Exploring Innovation in Firms

Heterogeneity, technological and organisational innovation,
and firm performance

Koson Sapprasert

PhD Thesis

Centre for Technology, Innovation and culture (TIK)
Faculty of Social Sciences
University of Oslo

April 2010

Series of dissertations submitted to the
Faculty of Social Sciences, University of Oslo
No. 232

ISSN 1504-3991

Cover: Inger Sandved Anfinsen.
Printed in Norway: AiT e-dit AS.

Produced in co-operation with Unipub, Oslo.
The thesis is produced by Unipub merely in connection with the
thesis defence. Kindly direct all inquiries regarding the thesis to the copyright
holder or the unit which grants the doctorate.

Abstract

Prior research on innovation covers a variety of important topics at the firm level. This thesis contributes to this line of research by focusing on a few major issues about "innovation in firms", i.e. heterogeneity, technological and organisational innovation, and firm performance. These issues relate mainly to the questions, "how do firms differ?" and "how does this matter to their innovative and other performance?" For example, previous studies are interested in the question of whether, and to what extent, innovation is persistent at the firm level, but little attention has been paid to explaining why some firms (do not) persistently innovate. This thesis proposes that firms' heterogeneity in the form of strategic differences across firms are an important determinant of innovation persistence, and analyses this by adopting a panel database from CIS (Community Innovation Survey) and R&D (Research and Development) surveys in Norway (Chapter 3). Another issue investigated by the thesis (i.e. the analysis in Chapter 4, which is also based largely on CIS and R&D survey data from Norway) is concerned with the questions, "is there really a positive link between ICT (Information and Communication Technology) and growth in services?" and "how does organisational change play a role in this?" These research questions are motivated particularly by the impressive upturn of the service industries, together with the increasing economic importance of ICT in these industries during recent decades. Prior research argues that innovation processes differ greatly according to the heterogeneity of firms, for example, some firms may complement ICT-based innovation with organisational change in order to make a significant improvement on their performance. Nonetheless, only a few empirical works at the firm level attempt to explain the remarkable growth of services based on this point. In Chapter 5, the thesis pays more attention to the organisational aspect of innovation, and seeks an explanation of the rates and effects of organisational innovation, whereas prior innovation research focuses much more on technological innovation, for example, in terms of new or radically changed products and processes. Despite the considerable importance of organisational innovation suggested by the literature, the relationship between firms' heterogeneity and this aspect of innovation has been taken into account in a much fewer number of quantitative analyses. On the basis of unique data on organisational innovation provided recently by the CIS, this chapter attempts to examine the heterogeneous factors which explain organisational innovation and its effects.

Two main quantitative methods used in this thesis are bibliometrics and econometrics. Following the introduction to the thesis (Chapter 1), Chapter 2 presents an overview of innovation studies, which is based on a bibliometric analysis of innovation literature. This

seeks to offer a broad picture of this line of research, for example, its organisation and development. One general conclusion which can be drawn from the analysis is that innovation studies is a fairly interdisciplinary field, in terms of both the production and the use of knowledge. The field encompasses research contributions from many disciplines, and these contributions are diffused and used across many research areas, such as management, business, engineering, economics and other social sciences. More specifically, one of the most important facts underscored by this chapter is that the literature has a strong focus on innovation in firms. Accordingly, the remaining chapters of the thesis (Chapters 3–5) attempt to address and challenge the aforementioned issues which have a great emphasis on innovation at the firm level, as well as its relationship with firms' heterogeneity. Based on a method which combines factor analysis, cluster analysis, and a dynamic random effects probit model, Chapter 3 provides evidence which confirms the general finding in the literature that innovation is persistent at the firm level. More importantly, this chapter found that observed firms' heterogeneity in terms of differences in strategies across firms explains why they (do not) persistently innovate. Based on an OLS (Ordinary Least Square) regression framework, Chapter 4 shows that ICT, combined with organisational change, is an important driving force behind the superior growth of service firms. Chapter 5 further examines determinants and effects of organisational change using Heckman two-step estimation. This chapter found that the rates of organisational change are influenced by factors such as firms' past economic performance, past attempt at organisational change and perceived costs of innovation, while the effects of organisational change are influenced by factors such as the persistence of organisational change and the complementarity of technical and organisational change. In addition, the results suggest that firm age and firm size have different impacts on the rates and effects of organisational change.

Acknowledgements

Finally, I have finished my PhD thesis. It has been a (long) journey full of learning, sharing, excitement, and sometimes just sheer pain! However, like many of my friends who have had a similar experience, I will never regret the several years I have spent working for my PhD.

I would like to take this opportunity to thank a number of people who, in one way or another, have been involved in my journey through the PhD life. First of all, I would like to thank my supervisor, Jan Fagerberg, for his various thoughtful suggestions and tremendous support since the very beginning of my PhD training. In fact, I was employed as his research assistant even before then. It has been my great pleasure to work with such a kind, supportive, clever and professional scholar like Jan. I believe that all of his PhD students agreed that they were very lucky to have him supervise their studies. He is an extraordinary supervisor, and I am truly indebted to him.

I would also like to acknowledge the help I have received from a number of research fellows at the Centre for Technology, Innovation and Culture (TIK). I am particularly grateful to Bart Verspagen, Tommy Clausen, Fulvio Castellacci, Martin Srholec, Merle Jacob, Mikko Pohjola, Magnus Gulbrandsen, and Sjur Kasa, who have closely cooperated with me all along the way, and offered me genuine friendship and good advice on my research work. In addition, I would like to thank Jarle Hildrum, Arne Fevolden, Siri Brorstad Borlaug, Jens Hanson, Svein Erik Moen, Jens Plahte, Olav Wicken, Linda Madsen, Morten Fosaas, Jon Holm, Bente Bleskestad, Hege Rudi Standal, and other TIK members for making my time there extremely enjoyable.

During the course of working for my PhD, I also spent a considerable amount of time at other academic institutes and participated in many projects/conferences. I would like to thank David Mowery, Trond Petersen, Jonas Jarut, Apinun Tachaplalert, Peerapong Pornwongthong, Somboon Chiewcharnpipat, Apin Sicoravit and many other fellows I met at the University of California Berkeley for the many stimulating conversations and great moments we shared on various occasions. I am also grateful for the excellent guidance and support of Walter Powell, James March, Annette Eldredge, David von Laskowski and others I met at Stanford University.

Apart from these academics, I also encountered a number of great people in the California Bay area. I would like to thank Tanantorn Jordan, Tom Pothikamjorn, Jack Amornvivat, Jonathan Chuvessiriporn, Tim Davis, Pamela Chayavichitsilp, Jakkapun and Jakris Boonchanya, Toy Bhirombhakdi, Tip-apa Limvichai and my other friends for their various kinds of support, and for making my year there such a pleasant one.

In Europe, I also had an opportunity to enjoy my PhD life at Cambridge University, where I got to know a number of interesting scholars. I would like to thank Paul Kattuman, Andrea Mina, George Hylden, Dmitry Sharapov, Rashedur Chowdhury, Carina Heppke, Andreas Markou, Chengwei Liu, Carmen Freitas, Pichawadee Kittipanya-ngam, Kelvin Ng and all the other folk there for sharing their considerable expertise with me. Also, I gratefully acknowledge the support of friends in other parts of the UK, especially Margaret Combey, Assawin Choochottavorn and Nattanee Kongsirikan.

During the first half of my PhD life, I was involved in a research project entitled "Understanding Innovation", and stayed for almost a year at the Centre for Advanced Study (CAS) at the Norwegian Academy of Science and Letters. During that fruitful academic year, I worked with, and learnt from, many wonderful colleagues. I am particularly grateful for the kind cooperation and encouragement from Ben Martin, Cristina Chaminade, Bengt-Åke Lundvall, Stan Metcalfe, Charles Edquist, Maryann Feldman, Tomas Hellström and Patarapong Intarakumnerd.

My PhD life has also been enriched by a number of younger scholars whom I met in several training sessions, and thereafter at various academic conferences. I would like to thank Sergey Filippov, Victor Perez Centeno, Vitor Hugo Ferreira, Bram Timmermans, Stefano Elia, Roberto Napoli, Kristian Reinau, Ismael Rafols, Dessy Irawati, Caroline Wamala and other classmates for many inspiring and interesting discussions.

Furthermore, I must not fail to mention that the social aspect of my PhD life was especially magnificent, largely owing to the friendship and help I received from quite a few people from Thailand. I would like to thank them all, especially the Sukboonya family, Kamlang family, Tulyathan family, Panyayong family, Manasomjit family, Tongjai Tangsanga, Jakkit Nimsuwan, Bhusarun Sethanandha, Tanuwa Chuaisaeng, Kanidtha Gulbrandsen, Haruethai Thongrueng, Traiporn Leelakun and Narada Olaranont.

On some occasions, I also received support from people I have never met. I really appreciate the comments I received on previous drafts of some of the chapters included in this thesis from editors and anonymous referees at *Industrial and Corporate Change* and *Structural Change and Economic Dynamics*.

In terms of financial support, which is, of course, indispensible, I would like to thank my employer, the Faculty of Social Science, University of Oslo, and other funding institutions and projects, particularly the MICRO-DYN (stands for "Micro-Dynamics", see www.micro-dyn.eu) project, DIME (Dynamics of Institutions and Markets in Europe) network of excellence, COST-STRIKE (European Cooperation in Science and Technology – Science and Technology Research In a Knowledge-based Economy), and CAS for financing my research work (and travels!).

Finally, I would like to express my huge gratitude to all my family members who have never stopped providing me with their love and all kinds of support. Without them, I would not have been able to survive my (PhD) life.

Contents

Chapter 1
INTRODUCTION[1]

1. Introduction

Innovation is an extremely popular topic of research nowadays. More than a thousand researchers, over a hundred research centres, and quite a number of academic journals focus on understanding innovation (Fagerberg and Verspagen, 2009). These constitute an area of research which produces knowledge of innovation, which is not only shared among the researchers themselves, but with those in many other disciplines/fields, together with a broad range of knowledge-users outside academia, such as firms, public organisations and individuals. However, it is important to note that innovation studies is a relatively new research area.[2] In the early part of the 20th century, at a time when social sciences were still emerging, very little attention was paid to this subject. One exception was the dedication of Joseph Schumpeter (1911, 1939, 1942), an Austrian scholar, who advanced the theory that innovations (particularly at the firm level), and the various social actors underpinning them, can be seen to be the driving forces of economic development.

Topics related to innovation received more attention around the time of the Second World War, as policy makers, firstly in the US and then elsewhere, became interested in Research and Development (R&D) and innovation, which they regarded as being an important impetus to progression in the military and, to a lesser extent, in the civil sector. However, it was not until around the 1960s, half a century after Schumpeter first presented his theory and a decade after his death, that there was a real surge of interest in innovation research. During the course of a few years in this decade, several important contributions emerged from several research disciplines, such as economics (Nelson, 1959; Schmookler, 1966), management (Penrose, 1959; Burns and Stalker, 1961) and sociology (Rogers, 1962). From that time onward,

[1] The author would like to thank Jan Fagerberg for his comments on earlier drafts of this chapter.

[2] See for instance, Fagerberg (2004) and Castellacci et al. (2005) for a good introduction to innovation studies.

research in this field flourished, and experienced a particularly strong growth in the 1990s (see Chapter 2 for a detailed discussion).

Following the key original contributions of Schumpeter (1911, 1942) and Nelson and Winter (1982), innovation research places emphasis on innovation in firms, among other things. The growing amount of literature about firm-level innovation includes a variety of topics, such as sources of innovation (Leonard-Barton, 1995; von Hippel, 1988), innovation processes (Rosenberg, 1982; Kline and Rosenberg, 1986), the diffusion of innovation (Rogers, 1962; Mansfield, 1961, 1985), innovation networks (Freeman, 1991; Powell et al., 1996), knowledge and learning (Arrow, 1962; Cohen and Levinthal, 1989, 1990; Grant, 1996; Nonaka and Takeuchi, 1995; Senge, 1990), resource and capabilities (Penrose, 1959; Barney, 1991; Teece et al., 1997; Wernerfelt, 1984), firms' behaviour (Cyert and March, 1963; Greve, 2003), strategies (Brown et al., 2000; Chandler, 1962; Porter, 1980; Kanter et al., 1997), success and failure (Christensen, 1997; Henderson and Clark, 1990; Rothwell et al., 1974), competitiveness (Teece, 1986; Prahalad and Hamel, 1990), economic growth (Dosi, 1988), technical change (Mansfield, 1968; Mansfield et al., 1981) and organisational change (Burns and Stalker, 1961; Romanelli and Tushman, 1994).

This thesis investigates several issues related to the topic of innovation at the firm level. Following this introduction, the thesis provides an overview of the core literature on innovation, with emphasis on its central thematic priorities among other things (Chapter 2). One of the most important facts underscored by this overview is that innovation studies have a strong focus on innovation in firms. Therefore, the remaining chapters of the thesis (Chapters 3–5) attempt to address and challenge some firm-level issues of innovation studies which do not appear to have received sufficient attention from prior research. Previous studies, such as those undertaken by Geroski et al. (1997), Malerba and Orsenigo (1999), Cefis and Orsenigo (2001), Raymond et al. (2006) and Peters (2009) take into account the path-dependent nature of innovation, and question the persistence of firms' innovation. However, the results of these studies are mixed, i.e. no clear conclusions can be drawn from them as to whether or not firms persist in innovation. More importantly, these studies did not investigate, or supply explicit evidence of the determinants of innovation persistence at the firm level. Thus, Chapter 3 of this thesis endeavours to provide more satisfactory answers to the questions, "Is innovation persistent at the firm level?" and "What are the factors which contribute to this?"

Another issue investigated by the thesis (Chapter 4) relates to the questions, "Is there really a positive link between Information and Communication Technology (ICT) and growth in services?" and "How does organisational change play a role in this?" These research questions are motivated by the impressive upturn of the service industries, together with the increasing economic importance of ICT in these industries during recent decades. Bresnahan et al. (2002), Brynjolfsson and Hitt (2000, 2003) and Brynjolfsson et al. (2002) argue that ICT-based innovation and organisational change complement each other in improving a firm's performance, so that its economic success is likely to be significant, especially if these two types of change are undertaken jointly. Nonetheless, only a few empirical works at the firm level attempt to explain the remarkable growth of services based on this point (for example, see Hempell et al., 2004). Chapter 5 pays more attention to the organisational aspect of innovation, and "seeks an explanation of the rates and effects of organisational innovation", whereas prior innovation research focuses much more on technological innovation, for example, in terms of new or radically changed products and processes. Despite the considerable importance of organisational innovation (for example, in economic 'forging ahead' and 'catching up' at different points in time, Bruland and Mowery, 2004), it has been largely neglected. This aspect of innovation has been taken into account in a much fewer number of (quantitative) analyses (see Chapter 2), which is mainly due to the availability of statistics.[3] On the basis of novel data on organisational innovation provided by the Community Innovation Survey (CIS), this chapter attempts to examine the factors which explain organisational innovation and its effects.

The introduction to the thesis is organised as follows. The next section discusses the main theoretical aspects of the thesis, as a way to provide a link to the research topics in each chapter. This is followed by an account of the data in the analyses of this thesis, which is mainly obtained from the CIS and the ISI Web of Knowledge. Next is an overview of the thesis, which includes a brief description of the theories and methodologies used in each chapter of the main body (Chapters 2–5), as well as their main conclusions. The final section summarises the major findings of the thesis. It also provides some implications, discusses limitations, and makes recommendations for future research.

[3] Empirical research on technological innovation may rely on, for example, patent or R&D data, while it is more difficult to measure organisational innovation, which is generally less tangible in character. See also Chapter 2 for a discussion on this point.

2. Theoretical Focus

This section provides an outline of the theories and concepts used in the thesis. First of all, it is important to note that the first study (Chapter 2) somewhat differs from the remainder (Chapters 3–5) in terms of objective and function. As discussed earlier, Chapter 2 was written to present a literature-based overview of innovation studies, with the intention of offering a broad picture of this line of research, for example, its organisation and development, and its relationship with other areas of research (see further discussion below). Central to Chapters 3–5 is the purpose to investigate some specific topics of research into innovation and, more importantly, to contribute to such research topics. Many aspects of these chapters are common, and as already mentioned, the focus is on the *firm level*. This is of the essence, since innovation in firms is crucial to their development and growth *per se*, as well as to the development and growth at higher levels (industries, countries, regions, and the world). The significance of firm-level innovation was proposed long ago by Schumpeter, firstly with a focus on the role of small firms, in that entrepreneurs are capable of introducing (radical) innovation to the market, which may devastate the value of incumbent firms ("creative destruction", Schumpeter Mark I, 1911). Later, he more extensively emphasised the relevance of knowledge and other resources accumulated by large firms, for example, through R&D activities, for their innovation process ("creative accumulation", Schumpeter Mark II, 1942). These two contrasting views of the relationship between firm size and innovation are addressed in a large body of literature on the so-called "Schumpeterian Hypotheses".[4] Aside from the issue of firm size (this is discussed in greater detail in Chapter 5), of particular importance is the function of a firm to produce, use and share knowledge, which depends considerably on a firm's interaction with its environment. This knowledge, which is produced, used and shared by different (groups of) firms (and other economic agents), differs greatly according to the *heterogeneity* of firms (see Chapter 3 in particular for an analysis which largely takes this into account). Firms see things differently, operate under different decision rules, and have different actions and reactions (even) to the same things. This explains why some firms are (not) aware of the need for innovation, and why, when they do innovate, they do it differently. Leiponen and Drejer (2007) and Srholec and Verspagen (2008) indicate that innovation processes/activities are much more heterogeneous across firms than across industries or countries, and based on this, one may even argue that innovation

[4] See Cohen and Levin (1989), Kamien and Schwartz (1975, 1982) and Scherer (1980) for good discussions on this.

diversity is much higher at the firm level than at the industry or country level.[5] This thesis mainly considers the essence of innovation in firms, and Chapter 3 particularly looks at the persistence of innovation in industrial firms, while Chapter 4 focuses on the relationship between the growth of service firms, and ICT and organisational change. Chapter 5 considers both manufacturing and service firms, and examines the factors which explain organisational change and its effects. More details of each chapter are given below in a synopsis of the thesis.

Next, this introduction seeks to explicitly acknowledge the relevance of *evolutionary economics* (Nelson and Winter, 1982) to innovation research, as well as to the fundamentals of the thesis. An evolutionary approach, which was inspired by these two renowned American evolutionary scholars and their European counterparts (for example, Dosi et al., 1988; Metcalfe, 1998), highlights the role of innovation as the main driver of competitiveness and growth.[6] In short, the evolutionary process in an economic context may be described by saying that firms are heterogeneous agents, exploring and exploiting knowledge in various forms, to cultivate their innovation. This leads to *variation* among products, processes and organisational forms. While successful innovators may be rewarded, for example, with better performance and competitiveness, firms which do not innovate, or fail to profit from their innovation, run a high risk of being punished by the market's *selection* mechanism. In this situation, whilst some heterogeneity remains, much of it is eliminated. The remaining/selected heterogeneity (i.e. in terms of products, processes, organisational forms) is then diffused, but firms need to retain their heterogeneity if they are to reproduce, and reap the fruits of it (i.e. *retention)*. At some point, some firms re-innovate, and so a new variety appears, and the evolutionary process is repeated.[7] The economic system is never stable, and technological advancement is continuous, since this process is unending.

The foregoing seems to imply that, in order to survive and stay competitive in industrial dynamics, one of a firm's crucial tasks is to keep learning and collecting knowledge relevant to innovation which, nonetheless, may or may not create more variety in the market (i.e. a

[5] This view seems to challenge a research strand of innovation systems (mainly sectoral and national innovation systems). This research strand argues that differences across sectors/nations account, to a considerable degree, for the rate and performance of innovation. See in particular, Pavitt (1984), Malerba (2004), Freeman (1987), Lundvall (1992) and Nelson (1993).

[6] See Fagerberg (2003) for a good introduction to the literature on evolutionary economics.

[7] For a detailed account of the evolutionary process, see, e.g., Aldrich (1999).

"new to the market/world" versus "only new to the firm" distinction). Such knowledge is embodied in a firm's *routines*, i.e. it is naturally encoded and saved, and becomes a (new) part of the operational process of the firm. Organisational routines reflect the firm's decision rules for standard operations and investments, and the modification of the rules themselves (Nelson and Winter, 1982). Although firms can change these rules or routines on the basis of their deliberate search, consistent with the Inertia theory (Hannan and Freeman, 1984),[8] the evolutionary view recognises the power of path-dependence. Many firms tend to do things in the same way time after time, and this is also reflected in their innovative behaviour (i.e. *innovation persistence*). The main reason for this is that firms typically prefer to use existing knowledge, i.e. something with which they are truly familiar, in their business operations and innovative activities.[9] This topic is at the heart of Chapter 3, and Chapter 4 also considers the persistence of organisational change, bringing this evolutionary element into the analysis.

It is worth noting that the evolutionary approach has essentially emerged as an alternative to the long-dominant neoclassical belief, which seems to misinterpret innovation. In the neoclassical research camp, firms are seen as being rational profit maximisers, their *innovation process* is modelled in a rather linear fashion, and knowledge is assumed to be equal to information and easily accessible by all firms.[10] On the contrary, firms can never have, or obtain, perfect knowledge through the evolutionary lens (i.e. bounded rationality), and neither can knowledge be seen as being public goods (Metcalfe and Georghiou, 1998). Knowledge and its application are dynamic and, therefore, they can never be in equilibrium (Metcalfe, 2007). In addition, in order to reap the fruits of knowledge spillover, firms need to build up an "absorptive capacity", i.e. an ability to recognise the value of new knowledge, and assimilate and apply it for commercial ends. This capability is, by and large, dependent upon

[8] However, it should be noted that, while Hannan and Freeman (1984) stress the power of organisational inertia and argue that most novelty comes from new entrants (i.e. established firms are more resistant to change), Nelson and Winter (1982) point out that established firms can also innovate based on their existing knowledge, as well as search for new knowledge. See Chapter 4 for detailed discussion.

[9] There are more explanations specifically for "innovation persistence", and Chapter 3 provides a discussion on this.

[10] For example, the neoclassical school, the foundation of which lies in the concept of a static equilibrium, regards knowledge as being a stock of free information in its recent theorising and modelling of economics, i.e. the so-called "new growth theory" developed by Lucas (1988) and Romer (1990), among others.

"the level of prior related knowledge" accumulated, for example, through R&D and learning by doing (Cohen and Levinthal, 1990:128).[11]

More importantly, Kline and Rosenberg (1986) point out that it may be inappropriate to treat innovation as a linear process, which begins with scientific research, followed by invention, and then innovation (for example, see the discussion in Fagerberg, 2004). This is not always the case, since in reality, the making of innovation involves many iterations (i.e. going back and forth between different stages), as well as interactions among various actors and components in a certain innovation system. In addition, an innovation (output) does not necessarily stem from science and/or research. Arundel et al. (2008) demonstrate that many innovative firms do not invest in R&D. Instead, many of them simply exploit their existing knowledge, or learn more from outside (March, 1991; Leiponen and Helfat, 2010). For instance, firms may adopt their customers, suppliers and competitors as sources of innovation (von Hippel, 1988). According to the taxonomy of innovation modes proposed recently by Jensen et al. (2007), beside a rather technical, research-intensive mode of innovation (STI–Science, Technology and Innovation), it is possible to innovate by Doing, Using and Interacting (DUI).

This last point provides a good link to another issue which is emphasised in this thesis, namely, the aspect of innovation which is less, or non-technological. This refers to the main concerns of Chapters 4 and 5 regarding *innovation in services,* and *organisational innovation*. For example, Evangelista (2000) and Miles (2004) propose that innovation processes in the service industries differ considerably from those in manufacturing, and this is because of the main characteristics of service activities, which are communication and information intensive, involving an enormous amount of interaction with suppliers and clients. Therefore, innovation in service firms usually focuses on these rather intangible and interactive features. In particular, ICT is thought to play a vital role in service innovation (Hipp and Grupp, 2005), since ICT helps to speed up communication and increase information channels, thus saving costs while boosting the quality and output of most service productions/operations. During recent decades, ICT has enabled the production of a technological platform upon which new

[11] This is also supported by the fact that knowledge is not simply information, and to gain and benefit from new knowledge is not as easy as it is to store new information. Metcalfe (2007) suggests trying to come to grips with the distinction between knowledge and information by considering that what can be seen or heard of a person is only the "representation" of his/her knowledge in the form of information. Given that this representation/information may not be perfect, certain knowledge one possesses may be hard, or impossible, to be fully realised by others.

services can be developed and existing ones can be much improved (Barras, 1986). This line of reasoning suggests a productive relationship between ICT and services. Whether, and to what extent, ICT affects the performance of service firms is empirically assessed in Chapter 4.

In addition, service innovation and/or ICT-based innovation may be complemented by organisational change in improving firm performance. The *complementarity* of technological and non-technological innovation is the key to successful improvement, because these two aspects of change are greatly interdependent. An effort to innovate technologically will only achieve limited success unless it is complemented by organisational change (Chandler, 1962), i.e. their co-evolution is part and parcel of real economic progress (Nelson, 1991). Firms may not achieve a competitive advantage by simply plugging in computers (Bresnahan et al., 2002). The contribution to a superior performance of a general-purpose technology[12] like ICT, would actually become significant when combined with re-organisation (Brynjolfsson and Hitt, 2000, 2003; Milgrom and Roberts, 1990). The complementary effects of technological and organisational innovation are addressed and analysed in Chapters 4 and 5.

Factors explaining organisational innovation and its effects are further investigated in Chapter 5. In line with the work of authors such as Pettigrew and Fenton (2000), this facet of innovation is non, or rather less, technological, and refers specifically to innovative change in a customary, institutional manner to an organisation's nature, structure, arrangement, practices, beliefs, rules or norms, which may be subsumed under one of Schumpeter's innovation categories, namely "a new way of organising business" (1911, 1942). Organisational innovation is crucial, since, due to industrial dynamics, some of the best practices or routines of a firm may turn out to be less effective, or even no longer acceptable, especially when compared with those of more innovative firms (Dosi and Nelson, 1994). In order to survive and remain competitive, the firm has then to search for better solutions and undertake changes (Nelson and Winter, 1982; Teece and Pisano, 1998), particularly if its performance falls below its "aspiration level", or a new window of opportunity opens up (Cyert and March, 1963; March and Simon, 1958). However, as discussed earlier, firms have diverse characteristics, and thus, they think and behave differently. This also refers to differences in the way firms decide to attempt routine changes, and the benefits which are

[12] There is a string of research focusing on general-purpose technologies, which are regarded as technologies which can be widely applied to, and have pervasive effects on, technical and economic developments. Examples include the steam engine, electricity and ICT. For examples, see Bresnahan and Trajtenberg (1995) and Carlsson (2004).

derived from such an attempt. As existing literature suggests, the organisational factors/characteristics which explain the likelihood and/or the effects of organisational innovation include, among others, variation in performance (March and Shapira, 1992; Greve, 2003), obstacles such as scarce resources (Kline and Rosenberg, 1986), the persistence of innovation (Kelly and Amburgey, 1991; Malerba and Orsenigo, 1999), the complementarity of technological and organisational innovation (Nelson, 1991), firm age (Amburgey et al., 1993) and firm size (Aldrich and Auster, 1986; Hannan and Freeman, 1984; Kimberly and Evanisko, 1981). This issue is examined at length in Chapter 5.

3. Empirical Data

The empirical part of this thesis relies upon two different types of data. The analysis in Chapter 2 has the objective of identifying and exploring existing literature about innovation studies, and is, thus, based on bibliometric data. In order to examine several issues about innovation in firms, the analyses in the other chapters (Chapters 3–5) employ survey-based data from Norway. This section provides a discussion about the data used in each chapter.

The bibliometric data used in Chapter 2 refers to citation indices from the ISI Web of Knowledge, and references from several important books (e.g. textbooks, handbooks and surveys) of innovation studies. These two sources of data together provide records on citations from/to journal articles, as well as from/to books. This combination essentially supplies an analysis with comprehensive information about the production, diffusion and use of knowledge in this research area, which, as discussed below, are the main interests of Chapter 2.

Citation data is helpful in analysing the organisation and development of a research area because it can be used to identify knowledge producers (cited publications/authors), users (citing publications/authors), and the relationships among them (knowledge transfer, etc.). This data may also be used to objectively measure the influence of authors/publications (citation counts),[13] and it is also possible to distinguish some main themes or issues in a research area by examining the pattern/formation of certain groups of citations. However, citation data must be used with caution, because it may not provide a perfect measure of a publication's impact on a research area. It is not always the case that a high citation count of a

[13] Many studies report a correlation between a publication's citation count and its academic influence. For example, see Cole and Cole (1973) and Martin and Irvine (1983).

book/article guarantees its high impact, since, in fact, that count may contain some citations from self, or courtesy references (Gunzburg et al., 2002), or may be due to the selectivity of citations by citing authors. For example, widely available books/papers may receive more citations compared to those which have not been well disseminated (Reedijk, 1998). Nonetheless, Simkin and Roychowdhury (2006) provide evidence revealing that many references have not been read, but simply copied from other papers, by citing authors.

In particular, even in a major source like the ISI Web of Knowledge, it is easy to find (a number of) citation errors. Another common criticism of this widely used source refers to its coverage. ISI only catalogues journals which are considered to be of excellent quality, and to have had a great impact on each research discipline. Based on such criteria (in which details are not disclosed by ISI), it is likely that new or small journals may be excluded (Cameron, 2005). More importantly, although it is possible, it requires considerable effort to extract citations (from articles in the journals within ISI coverage) "to books",[14] while it is not at all possible to obtain any citations "from books" (because ISI excludes books as a source of citations), from the ISI database. These difficulties often limit an analysis of knowledge which is produced, used by, and transferred from/to books (i.e. cited and citing books, the relationships among them, and with other publications). In fact, such knowledge is very important since, book publications are normally dominant in comparison with journal publications in emerging research fields, such as innovation studies.[15] As mentioned earlier, in order to obtain a comprehensive account of innovation literature for the analysis, both citations to books from ISI indices, and citations from books from several reference books of innovation studies, are also taken into account in Chapter 2.

The analyses in Chapters 3, 4 and 5 benefit from survey-based data on innovation in firms, for example, product/process innovation, R&D, and organisational innovation. Due to an increasing interest in innovation over recent decades, various efforts have been made to collect data for innovation research at all levels of aggregation, and these efforts exist, not only in developed countries, particularly European countries, but also in less developed countries, such as Brazil and Thailand.[16] The data made available by these efforts does not

[14] This is possible, in a rather manual manner, by means of a cited reference search in ISI.

[15] Chapter 2 provides a discussion on this point.

[16] For a good discussion on innovation surveys, see Fagerberg et al. (2010) and Smith (2004).

only concern innovation in a technological sense, such as R&D and product/process innovation, but also non-technological innovation, such as organisational change. Among others, the most remarkable survey-based effort is probably the so-called Community Innovation Survey (CIS). Based on the Oslo Manual (published in three editions, in 1992, 1997 and 2005) developed jointly by Eurostat and OECD (2005), the CIS has been conducted five times so far, for the periods between 1990 and 1992, 1994 and 1996, 1998 and 2000, 2002 and 2004, 2006 and 2008 in many European countries. The methodology used for the CIS has also been followed by innovation surveys in some countries outside Europe, such as Australia, Canada, China, Japan, South Korea and South Africa.

The firm-level innovation data used in Chapters 3, 4 and 5 is obtained mainly from three waves of the Norwegian CIS implemented by Statistics Norway (CIS2, 3 and 4). In Norway, the periods during which the CIS2 and 3 were conducted were one year later than in other countries, i.e. 1995–1997 and 1999–2001. Various sets of information, for example, about innovation objectives, innovation activities, and sources of information for innovation from the Norwegian CIS2 (1995–1997) are merged with information about product and process innovation from the R&D surveys (1995–2004), also carried out by Statistics Norway, for the analysis of the persistence of innovation in Chapter 3. Chapter 4 uses information from the combined CIS3 and R&D survey for the period between 1999 and 2001 (e.g. about R&D on ICT, product/process innovation and organisational change), and from the financial accounts of firms in Norway (1999–2003) in order to explore a link between ICT and firm performance, among other things. Chapter 5 integrates the CIS3 with the CIS4 and financial accounting data (hence, a dataset covering the period between 1999 and 2004), and explores organisational innovation and its effects.

In Norway, firms are obliged to respond to CIS and R&D surveys (and to report their financial accounts every year). Using the Norwegian data creates a great advantage for this thesis, because the surveys received a very high response rate (e.g. 93% and 95% for CIS 3 and 4, respectively), and therefore, they are capable of providing representative samples for the analyses. The CIS is also widely used in other countries, since it offers various indicators for innovation, from both a technological and non-technological perspective. The standard CIS includes a range of information on innovation, such as product and process innovation, objectives of innovation, information sources of innovation, obstacles to innovation, organisational innovation, and other innovation activities. This enables the formation of a detailed picture of innovation in firms, which is important for the analyses of many central research issues in innovation studies, as outlined in the previous section (for example, heterogeneity, routines, persistence, sources and effects of innovation). In addition, an increasing number of researchers prefer to employ CIS data in their studies because, for the most part, it is harmonised across the countries where the survey is conducted, and this harmonisation enables a coherent comparative analysis (cross-country, etc.).[17]

Nonetheless, there are some objections to the use of CIS data. For example, it is often criticised for having a cross sectional nature. Several CIS indicators refer to the same, or an overlapping, time period. Thus, these indicators may result in explanatory variables which are co-determined with a dependent variable, or explanatory variables which are highly correlated. This could instigate problems of multicollinearity, simultaneity or endogeneity, which may potentially cause a spurious causality or bias in an analysis. The time span of CIS is quite short, i.e. three years, which can also be problematic since, for instance, innovators may have too little time to realise the effects of their innovation. In addition, the design of many important questions in the CIS leads to dichotomous or categorical information, which cannot sufficiently explain heterogeneity. For example, there is information about the presence of (any) product, process, and organisational innovation, but not the number of innovations. Also, CIS data is based, in part, on the subjective evaluation or perception of the respondent firms. For example, there is a set of CIS questions about obstacles to innovation, which may simply lead to subjective indicators of factors of innovation (Clausen, 2008). Another problem potentially caused by the (same) respondents' evaluation relates to common method variance which can bias correlations between variables, i.e. common method bias. This may be the case when common scale formats and/or anchors are used consecutively in a questionnaire. Despite the fact that a mix of Likert scales and questions which require to be answered in a binary (yes/no) or numerical format (absolute number, percentage) are used in different parts throughout the CIS questionnaire, this may still be a problem when using CIS data,[18] for example, in the analysis of the determinants and effects of organisational innovation in Chapter 5. Moreover, many variables in the CIS are censored. Only product and/or process innovators are allowed to answer the questions pertaining to various details

[17] For a good example, see Srholec and Verspagen (2008).

[18] This simply means that the strong correlation between some CIS variables may be, in part, influenced by common method bias. Criscuolo et al. (2007), for instance, provide a discussion on this potential problem in the use of CIS data.

about innovation in firms, resulting in somewhat limited information about firms which have not attempted any product or process innovation. Thus, studies which only take account of product and/or process innovators often have to employ techniques like a Tobit or Heckman regression to correct for potential selection bias. The analyses in this dissertation are concerned with these important points. For instance, unobserved heterogeneity is accounted for in a dynamic random effects Probit model in Chapter 3. The analysis in Chapter 4 uses explanatory and dependent variables which are constructed based on information from different time periods when examining a causal relationship between ICT and organisational change on the one hand, and firm performance on the other. To avoid a selection bias in the analysis, Heckman's (1979) two-step model is employed in Chapter 5.

4. Thesis Synopsis

The main body of this thesis is built upon four research articles (Chapters 2–5), and despite there being several links among these chapters, they may be read as independent pieces. The four articles concern the organisation and development of innovation research itself (Chapter 2), the persistence of innovation and its relationship with a firm's strategies (Chapter 3), the relationship between ICT and a growth in services (Chapter 4), and the determinants and effects of organisational innovation (Chapter 5). The following is an overview of each chapter:

Chapter 2 explores the field of innovation studies by focusing on core innovation literature which has contributed to the development of this field since the early nineteenth century, when a few influential pieces of innovation-related research work began to emerge, notably those of Schumpeter. The analysis indicates that innovation studies began to attract greater social and scholarly attention around the middle of the century, and that the past few decades have, therefore, witnessed an increasing number of studies devoted to investigating various topics regarding innovation. Apart from the supply (side) of knowledge within this research field, this chapter examines the ways in which this knowledge has been disseminated and exploited over time. The chapter provides descriptive and empirical evidence (from bibliometric and cluster analyses) based on the above-mentioned data, not only obtained from the ISI database (which is typically used in other bibliometric studies, for example, citation analysis), but also from several major reference books within innovation studies. Together, these enable a novel approach to a bibliometric analysis.[19] One general conclusion which can be drawn from the analysis of innovation literature is that innovation studies is an extremely interdisciplinary field, in terms of both the production and the use of knowledge. The field encompasses research contributions from many disciplines, and these contributions are diffused and used across many research areas, such as management, business, engineering, economics and other social sciences. In addition, the core innovation literature is identified, and classified into a few main groups based on their key characteristics, for example, disciplinary orientation (subject area categories), thematic focus (keywords) and dissemination channels (publication outlets). As discussed above, much of this core literature has a focus on innovation in firms, and is also referred to in different theoretical discussions in this thesis (for instance, Schumpeter, 1911, 1942; Penrose, 1959; Nelson and Winter, 1982; Rosenberg, 1982; Dosi, 1988; Cohen and Levinthal, 1990).

The thesis continues with a closer examination of some research topics on innovation in firms which seem to deserve further investigation.

Chapter 3 concerns the probability and sources of innovation persistence, and analyses these using a combination of analytical methods (factor analysis, cluster analysis and dynamic random effects Probit regression), which allows for the accounting of firm heterogeneity in a more elaborate way than has so far been customary.[20] The analysis based on the panel data of Norwegian firms in industry (mining, manufacturing, public utilities and construction) confirms persistent innovation, especially in larger firms. This persistence is also found to be more robust in product innovation than in process innovation. As an attempt to add a new contribution to the existing literature on innovation persistence, the observed heterogeneity among firms is operationalised in the analysis. The results demonstrate that heterogeneity, in terms of difference in innovation strategies across firms, does play a major role in explaining persistent innovative behaviour at the firm level. For instance, firms which are active in every aspect of innovation (for example, investing in both in-house R&D and technology acquisition, innovating with a focus on production as well as market, having various sources

[19] See Chapter 2 for a discussion on this.

[20] Prior empirical studies of the topic of innovation persistence include Geroski et al. (1997), Cefis (2003), Peters (2009), Raymond et al. (2006). See Chapter 3.

of information for innovation[21]) appear to be particularly persistent in both product and process innovation. In addition, the results suggest differences with regard to innovation persistence in high-tech and low-tech sectors. Product innovation, which usually requires more strategic decision-making and technological advancement (Rosenberg, 1982; Tushman and Rosenkopf, 1992), appears to be more persistent than process innovation in the high-tech sector, while the opposite is true in the case of low-tech firms.

Chapter 4 shifts the focus to innovation in services, and links the essence of a modern day general-purpose technology, like ICT (Bresnahan and Trajtenberg, 1995; Carlsson, 2004), with the rise of service industries over recent decades. This supports the view that ICT is a new key ingredient of innovation in services (Castellacci, 2006; Hipp and Grupp, 2005; Tidd et al., 2005), which may have led to the service industries catching up with, and nowadays outperforming, the manufacturing industries (OECD, 1996).[22] Nonetheless, the analysis in this chapter remains at the firm level. The chapter's main argument is that service firms benefit (more than manufacturing firms do) from innovation based on ICT, in great part because of their basic interactive and information-intensive characteristics (i.e. a vast amount of interaction with their clients and suppliers),[23] which are highly compatible with this technology. This compatibility makes for an "ICT-friendly" atmosphere. This is an atmosphere which seems conducive to service innovation, which increasingly depends upon the adoption of this technology for improving and facilitating the immense transactions involved in most service operations/activities. In addition, in line with Bresnahan et al. (2002) and Brynjolfsson and Hitt (2000, 2003), organisational change is purported to complement ICT in boosting the performance of service firms. This is because, as discussed above, the two aspects of change are interdependent and complementary. The success of a firm's attempt at technological innovation is limited unless it is accompanied by a process of reorganisation. Thus, ICT-based innovation in services needs to be reinforced by organisational change if the firm is to benefit significantly from this technology. The results of an OLS (Ordinary Least

[21] This refers to the group of High-profile firms identified by the analysis in Chapter 3. A detailed explanation is provided in the chapter.

[22] The manufacturing industries were the major contributor to the worldwide economy for a number of decades, remarkably since the first industrialisation. However, around the 1960s, service industries began to play a more important role, and innovation in services has thus received greater scholarly attention throughout recent decades. For example, see Andersen et al. (2000), Barras (1986), Metcalfe and Miles (2000)

[23] These are very significant characteristics of business operations in services, as stressed by, for example, Evangelista (2000) and Miles (2004). See Chapter 4 for a discussion.

Squares) regression framework, based on the combined Norwegian CIS3, R&D and financial accounts (1999–2003), support the chapter's main arguments by demonstrating that the presence and intensity of ICT (during 1999–2001) explain the higher growth enjoyed by service firms (during 2001–2003). The complementary effect between ICT and organisational change is also evident. The service firms which invested in ICT while jointly attempting organisational change were found to have achieved an even better economic performance. This finding highlights the fact that ICT necessitates reorganisation.

Chapter 5 stresses the importance of, and more closely examines, this organisational facet of innovation (a non or less-technological, customary, institutional way of changing how firms organise works). The chapter's main objective is to examine the factors which influence a firm's decision to attempt organisational innovation, and/or which influence the effects of organisational innovation on a firm's performance. As mentioned earlier, while this decision is possibly affected by variations in firm performance and some obstacles to innovation (Cyert and March, 1963; Mohr, 1969), the effects of organisational innovation may increase with persistence (Kelly and Amburgey, 1991) and efforts in technological innovation, which is often seen as being complementary (Nelson, 1991). Because of their properties,[24] firm age and size also may influence the rate and effects of organisational innovation (Amburgey et al., 1993; Aldrich and Auster, 1986; Hannan and Freeman, 1984; Kimberly and Evanisko, 1981). The (Heckman 2-stage[25]) analysis, based on the integrated dataset of two recent waves of the Norwegian CIS (CIS3 & 4) and financial accounts, takes these factors into consideration when explaining organisational innovation and its effects. In addition to the evidence of technological innovation persistence in Chapter 3, the results of this chapter report the persistence of organisational innovation, and this persistence appears to increase the positive effects of organisational innovation on firm performance. Moreover, a firm's decision to attempt organisational innovation is found to be driven by low profits, but hampered by high costs of innovation. There is also evidence that a number of the sampled firms had attempted and benefitted from organisational change, and that these benefits could have been increased if such a change had been complemented by technological innovation. The likelihood and consequences of organisational innovation are also explained, in part, by firm age and size.

[24] See a detailed discussion on age and size properties in Chapter 5.

[25] A Heckman two-step estimation is employed to handle potential sample selection bias since information on the effects of organisational innovation is only available for organisational innovators in the sample. See Chapter 5.

The results suggest that these two characteristics have different impacts on firms. While older, larger firms have a higher probability of attempting organisational change, smaller firms benefit more from making such an attempt.

The table below presents the title and a brief note about the four chapters constituting the body of the thesis.

Chapter	Title	Note
2	Innovation: exploring the knowledge base	• Co-authored with Jan Fagerberg
3	Innovation Strategies as a Source of Persistent Innovation	• Co-authored with Tommy Clausen, Mikko Pohjola and Bart Verspagen, submitted to *Industrial and Corporate Change*
4	ICT and Growth in Services: is there really a link?	• Revised and resubmitted to *Structural Change and Economic Dynamics*
5	Determinants and Effects of Organisational Innovation	• A shortened version published in Ostreng, W. (2009) (ed.) *Confluence: Interdisciplinary Communications 2007/2008*. CAS, Norway, with the title "Acknowledging Organisational Innovation" • Revised and resubmitted to *Industrial and Corporate Change*

5. Concluding Discussion

Innovation studies is an emerging field of research which is fairly interdisciplinary. The field covers various aspects of innovation, and has strong connections with several major research disciplines, such as management, economics and other social sciences. This thesis places emphasis on the organisation and development of innovation studies, and investigates some important topics within this research field. Apart from an overview of the core literature, which touches upon a range of research themes in innovation studies (Chapter 2), the integral parts of this thesis include an analysis of innovation persistence, a key current technological innovation, like ICT, and organisational change (Chapters 3–5).

It is important to mention that the analyses in Chapters 3–5 relate to innovation in Norway, the country which has provided the main empirical data used in this thesis. The Norwegian economy is rather unique, and thus, this country's innovation systems/processes are worth investigating. This uniqueness is often referred to as the "Norwegian paradox", because although the country's economic performance is remarkable, Norway has invested relatively little in R&D and innovation compared with other industrialised countries (Gronning et al., 2008; OECD, 2007).[26] It may simply be argued that this phenomenon is, by and large, due to the discovery of enormous oil and gas supplies in Norwegian waters since the 1970s. Nonetheless, other European countries such as Denmark, the UK, and the Netherlands have also found such valuable natural resources, but it seems that Norway has more successfully managed to reap the benefits of this discovery (Fagerberg et al., 2009). For example, in contrast to the Dutch case which centred on a de-industrialisation approach, Norway launched a strategy to develop several domestic manufacturing and service industries based extensively on the flourishing growth of the oil and gas industry (Engen, 2009). This, in turn, substantially fosters the country's system of innovation (Fagerberg et al., 2009). Put differently, the economic success derived from exploiting natural resources only partly accounts for Norway's impressive wealth. Of greater importance is its indirect growth contribution, i.e. this success supports the development and interaction of various components in the Norwegian innovation system, and therefore, it helps to leverage the country's economic performance (Freeman, 1987; Lundvall, 1992; Nelson, 1993). This is the key distinctive characteristic of innovation in Norway.

The empirical results of this thesis, based on data of Norwegian firms, may provide some insights and implications for the Norwegian public. For example, the thesis demonstrates that Norwegian firms generally benefit from organisational innovation, and that many of them are persistent organisational innovators, and they benefit even more from this persistence. In terms of industrial activities, Norwegian firms are also persistent in technological innovation. Moreover, when technological and organisational innovation are undertaken jointly, Norwegian firms seem to receive even greater benefits due to the complementary effect. This is particularly the case of Norwegian service firms which combine R&D on ICT with

[26] However, Fagerberg et al. (2009) point out that the measures used for these statistical assessments may be flawed, and adhere to the linear model of innovation (see above for a discussion on this model). They suggest that innovation should be studied as a historical, systemic, interactive process.

reorganisation. Obviously, these findings offer some policy recommendations and managerial implications for firms in Norway (and elsewhere). For example, organisational change pays off, since it supports technological innovation, such as ICT, in boosting firm performance, especially in the service industries. Furthermore, organisational innovation may yield greater benefits if carried out persistently. In fact, these important elements (the organisational facet of innovation, persistence and complementarity), which are normally unreported and unavailable in the statistics, may have contributed, at least to some extent, to Norway's outstanding growth, and may partly explain the paradox of the Norwegian case.

Several of the findings of this thesis support prior empirical studies of other countries. For instance, Crepon and Duguet (1997) and Duguet and Monjon (2004) found high innovation persistence among French firms. Rogers (2004) obtained similar results from his study of firms in Australia. Castillejo et al. (2004) also reported a positive influence of R&D experience on a decision to conduct a new round of R&D in Spanish firms. More recently, Peters (2009) provided evidence of the innovation persistence of firms in Germany. Chapter 3 reports the findings which support these studies, and also makes an important extension by trying to determine what makes (Norwegian) firms persist in innovation. Also, the results of Chapter 4 substantiate a productive relationship between ICT and services, as suggested by an analysis of German and Dutch firms by Hempell et al. (2004) and that of Italian firms by Cainelli et al. (2004). However, the analysis of Norwegian firms in this thesis (Chapter 4) especially focuses on the question of how R&D on ICT influences a service firm's growth in terms of productivity and profitability. The complementary effect of technological and organisational change, which is another key focus of this thesis (Chapters 4 and 5), is also revealed by several studies from the US, for example, those of Brynjolfsson and Hitt (2000, 2003) and Brynjolfsson et al. (2002).[27]

It is natural to also discuss some limitations associated with the analyses in this thesis. The main limitations relate to the data used. As noted earlier, the data on innovation provided by

[27] Nonetheless, some of the results of this thesis differ from those suggested by previous research. Examples include Geroski et al. (1997), Malerba and Orsenigo (1999) and Cefis and Orsenigo (2001), which found low, or no, clear-cut persistence of innovation in the UK, the US, Japan and a few European countries. However, these studies employed patent data to measure innovation, which, as discussed in Chapters 3, could be problematic (e.g. patent seems closer to invention than innovation). In terms of the effect of complementary changes which is an important issue in this thesis (Chapters 4 and 5), Hempell et al. (2004), for instance, show that the joint impact of ICT and non-technological innovation on firm growth may not be significant, but that this is a case only for Dutch firms which undertook non-technical innovation on an occasional basis.

the CIS (and R&D surveys) is not available at the project or plant level (this data is most detailed at the firm level), and only contains information about some sets of activities and circumstances. Thus, it was not possible to fully observe heterogeneity in the innovation processes. This calls for more and better measures of innovation, and of other relevant factors, for empirical innovation studies. Moreover, the effects of innovation could not be thoroughly examined because CIS data has a short time span (i.e. three years), which only allows such effects to be realised in the near term. For this reason, the analysis in Chapter 4 for example, instead investigates how innovation affects firm performance in a subsequent period. Another important limitation is due to the cross sectional nature of the CIS. Its cross sectional structure could lead to some flaws in the analysis, since certain variables extracted from CIS data may be co-dependent on other variables. In some cases, a series of CIS variables which are associated with the same scale format and/or anchors may be highly correlated, i.e. common method bias. This implies that future research using CIS data should also beware of potential technical/analytical problems (simultaneity, endogeneity, etc., which may, for instance, result in a spurious causality or bias). In addition, CIS data typically does not cover firms with less than 10 employees, and it contains incomplete information for non-innovative firms. It would indeed be worthwhile to further study innovation in smaller firms, as well as extending this research by looking more closely at the behaviour of non-innovative firms, such as by adopting other data sources.

Other crucial limitations include those connected with the scope of the study itself. For example, Chapter 2 focuses on the literature in innovation studies. This field of research is greatly interdisciplinary in itself,[28] and may have close connections with other fields, such as entrepreneurship and science and technology studies. Future research may also explore research fields related to innovation studies and their relationships. Chapter 3 on innovation persistence may be extended to include service firms, and a comparative analysis (i.e. industry versus services) may be undertaken, since service firms probably also have this persistent behaviour, but in a different way (for example, more persistence in process innovation than in product innovation). Given the unclear boundary between manufacturing and services, further research on the topic of concern in Chapter 4 may attempt to take account of service innovation which is possibly introduced outside service firms, due to the fact that a number of manufacturing firms also provide services nowadays. Chapter 5 places emphasis on the

[28] Chapter 2 provides detailed evidence and discussion regarding this point.

determinants and effects of organisational change, but these are not exhaustive. The chapter does not explore other relevant issues, such as the differential and complementary effects of different types of qualitative change in firms, and this is recommended for further research into organisational change. As discussed earlier, when taken together, the empirical studies in Chapters 3–5 relate exclusively to the innovation of firms in the Norwegian context. It would be interesting for future extensions to conduct a cross-country comparative analysis of the same, or similar, topics. It seems that this would be possible, since CIS data is also available in, and harmonised across, a number of countries, especially in Europe.

References

Aldrich, H. (1999), *Organisations Evolving.* SAGE: London

Aldrich, H. and Auster, E. (1986), 'Even dwarfs started small: liabilities of age and their strategic implications', *Research in Organisational Behavior,* **8**, 165-198.

Amburgey, T. L., Kelly, D. and Barnett, W. P. (1993), 'Resetting the Clock: The Dynamics of Organisational Change and Failure', *Administrative Science Quarterly,* **38(1)**, 51-73.

Andersen, B., Howells, J., Hull, R., Miles, I. and Roberts, J. (2000), *Knowledge and Innovation in the New Service Economy*. Edward Elgar: Cheltenham.

Arrow, K. (1962), 'The economic implications of learning by doing', *Review of Economic Studies,* **29(3)**, 155-73.

Arundel, A., Bordoy, C. and Kanerva, M. (2008), 'Neglected innovators: How do innovative firms that do not perform R&D innovation?', Results of an analysis of the Innobarometer 2007 survey, No. 215, INNO-Metrics thematic paper.

Barney, J. (1991), 'Firm resources and sustained competitive advantage', *Journal of Management,* **17(1)**, 99-120.

Barras, R. (1986), 'Towards a theory of innovation in services', *Research Policy*, **15**, 161-73.

Bresnahan, T. F. and Trajtenberg, M. (1995), 'General Purpose Technologies: 'Engines of Growth'?', *Journal of Econometrics*, **65**, 83-108.

Bresnahan, T. F., Brynjolfsson, E. and Hitt, L. M. (2002), 'Information Technology, Workplace Organisation, and the Demand for Skilled Labor: Firm–Level Evidence', *Quarterly Journal of Economics*, **117**, 339-376.

Brown, S., Lamming, R., Bessant, J. and Jones, P. (2000), *Strategic Operations Management.* Butterworth Heinemann: Oxford.

Brynjolfsson, E. and Hitt, L. (2000), ‘Beyond Computation: Information Technology, Organisational Transformation and Business Performance’, *Journal of Economic Perspectives*, **14(4)**, 23-48.

Brynjolfsson, E. and Hitt, L. (2003), ‘Computing Productivity: Firm-Level Evidence’, *The Review of Economics and Statistics*, **85(4)**, 793-808.

Brynjolfsson, E., Hitt, L. and Yang, S. (2002), ‘Intangible Assets: Computers and Organisational Capital’, *Brookings Papers on Economic Activity*, 137-198.

Burns, T. and Stalker, G. (1961), *The management of innovation.* Tavistock: London.

Cainelli, G., Evangelista, R. and Savona, M. (2004), ‘The impact of innovation on economic performance in services’, *Service Industries Journal*, **24(1)**, 116 - 130.

Cameron, B. (2005), ‘Trends in the Usage of ISI Bibliometric Data: Uses, Abuses, and Implications’, *Libraries and the Academy*, **5(1)**, 105-125.

Carlsson, B. (2004), ‘The digital economy: what is new and what is not?’, *Structural Change and Economic Dynamics*, **15**, 245-264.

Castellacci, F. (2006), ‘Innovation, Diffusion and Catching up in the Fifth Long Wave’, *Futures*, **38(7)**, 841-863.

Castellacci, F., Grodal, S., Mendonca, S. and Wibe, M. (2005), ‘Advances and Challenges in Innovation Studies’, *Journal of Economic Issues,* **39(1)**, 91-121.

Castillejo, M., Rochina Barrachina, M. E., Sanchis Llopis, A. and Sanchis Llopis, J. A. (2004), ‘A dynamic approach to the decision to invest in R&D: the role of sunk costs’, Universidad Valencia.

Cefis, E. (2003), ‘Is there persistence in innovation activities?’, *International Journal of Industrial Organisation,* **21(4)**, 489-515.

Cefis, E. and Orsenigo, L. (2001), ‘The persistence of innovative activities: a cross-countries comparative analysis’, *Research Policy,* **30(7)**, 1139-1158.

Chandler, A. (1962), *Strategy and Structure*. MIT Press: Massachusetts.

Christensen, C. (1997), *The innovator’s dilemma.* Harvard Business School Press: Massachusetts.

Clausen, T. (2008), ‘Search Pathways to Innovation’, TIK Working Papers on Innovation Studies, Centre for Technology Innovation and Culture, University of Oslo.

Cohen, W. and Levin, R. (1989), ‘Empirical Studies of Innovation and Market Structure’, in Schmalensee, R. and Willig, R. (eds), *Handbook of Industrial Organisation, Vol. 2.* Elsevier Science: the Netherlands.

Cohen, W. and Levinthal, D. (1989), ‘Innovation and Learning: the two faces of R&D – implications for the analysis of R&D investment’, *Economic Journal,* **99**, 569-96.

Cohen, W. and Levinthal, D. (1990), ‘Absorptive capacity: a new perspective on learning and innovation’, *Administrative Science Quarterly,* **35(1)**, 128-152.

Cole, J. and Cole, S. (1973), *Social Stratification in Science*. University of Chicago Press: Chicago.

Crepon, B. and Duguet, E. (1997), ‘Estimating the innovation function from patent numbers: GMM on count panel data’, *Journal of Applied Econometrics,* **12(3)**, 243-263.

Criscuolo, P., Nicolau, N. and Salter, A. (2007), ‘The elixir or burden of youth? Exploring differences among start-ups and established firms in innovation behaviour’, paper presented at the DRUID summer conference 2007, Copenhagen, 18 -20 June.

Cyert, R. M. and March, J. G. (1963), *A Behavioral Theory of the Firm.* Prentice Hall: New Jersey.

Dosi, G. (1988), 'Sources, procedures and microeconomic effects of innovation', *Journal of Economic Literature,* **26**, 1120-71.

Dosi, G. and Nelson, R. (1994), 'An introduction to evolutionary theories in economics', *Journal of Evolutionary Economics*, **4**, 153-72.

Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L. (eds.) (1988), *Technical Change and Economic Theory*, Pinter: London.

Duguet, E. and Monjon, S. (2004), 'Is innovation persistent at the firm level: An econometric examination comparing the propensity score and regression methods', Université Panthéon-Sorbonne (Paris 1).

Engen, O. A. (2009), 'The development of the Norwegian innovation system: a historical overview', in Fagerberg, J., Mowery, D. and Verspagen, B. (eds.), *Innovation, Path-dependency and Policy: the Norwegian case*. Oxford University Press: Oxford.

Evangelista, R. (2000), 'Sectoral patterns of technological change in services, economics of innovation', *Economics of Innovation and New Technology*, **9**, 183-221.

Fagerberg, J. (2003), 'Schumpeter and the revival of evolutionary economics: an appraisal of the literature', *Journal of Evolutionary Economics,* **13**, 125-159.

Fagerberg, J. (2004), 'Innovation: a guide to the literature', in Fagerberg, J., Mowery, D. and Nelson, R. (eds.), *The Oxford Handbook of Innovation*, Oxford University Press: Oxford.

Fagerberg, J. and Verspagen, B. (2009), 'Innovation Studies – the emerging structure of a new scientific field', *Research Policy,* **38(2)**, 218-233.

Fagerberg, J., Mowery, D. and Verspagen, B. (2009), 'Introduction: innovation in Norway', in Fagerberg, J., Mowery, D. and Verspagen, B. (eds.), *Innovation, Path-dependency and Policy: the Norwegian case*. Oxford University Press: Oxford.

Fagerberg, J., Srholec, M. and Verspagen, B. (2010), 'Innovation and Economic Development', in Hall, B. and Rosenberg, N. (eds.), *The Handbook of Economics of Innovation,* Elsevier: the Netherlands, *forthcoming.*

Freeman, C. (1987), *Technology Policy and Economic Performance: Lessons from Japan*, Pinter: London.

Freeman, C. (1991), 'Networks of innovators: A synthesis of research issues', *Research Policy,* **20**, 499-514.

Geroski, P. A., van Reenen, J. and Walters, C. F. (1997), 'How persistently do firms innovate?', *Research Policy,* **26(1)**, 33-48.

Grant, R. M. (1996), 'Toward a knowledge-based theory of the firm', *Strategic Management Journal,* **17**, 109-122.

Greve, H. R. (2003), *Organisational Learning from Performance Feedback: A Behavioural Perspective on Innovation and Change.* Cambridge University Press: Cambridge.

Gronning, T., Moen, S. E. and Olsen, D. S. (2008), 'Low innovation intensity: High growth and specialised trajectories: Norway', in Edquist, C. and Hommn, L. (eds.), *Small-country innovation systems: Globalisation, change and policy in Asia and Europe,* Edward Elgar: Cheltenham.

Gunzburg, R., Szpalski, M. and Aebi, M. (2002), 'The impact factor: publish, be cited or perish', *European Spine Journal,* **11** Supplement 1.

Hannan, M. T. and Freeman, J. H. (1984), 'Structural Inertia and Organisational Change', *American Sociological Review*, **49(2)**, 149-64.

Heckman, J. (1979), 'Sample selection bias as a specification error', *Econometrica*, **47(1)**, 153-161.

Hempell, T., Van Leeuwen, G. and Van der Wiel, H. (2004), 'ICT, Innovation and Business Performance in Services: Evidence for Germany and the Netherlands', in OECD, *The Economic Impact of ICT—Measurement, Evidence, and Implications*, OECD: Paris.

Henderson, R. and Clark, K. (1990), 'Architectural Innovation: The reconfiguration of existing product technologies and the failure of established firms', *Administrative Science Quarterly,* **35**, 9-30.

Hipp, C. and Grupp, H. (2005), 'Innovation in the service sector: the demand for service-specific innovation measurement concepts and typologies', *Research Policy*, **34**, 517-535.

Jensen, M. B., Johnson, B., Lorenz, E. and Lundvall, B. –Å. (2007), 'Forms of Knowledge and Modes of Innovation', *Research Policy,* **36**, 680-693.

Kamien, M. I. and Schwartz, N. L. (1975), 'Market Structure and innovation: A survey', *Journal of Economic Literature,* **13(1)**, 1-37.

Kamien, M. I. and Schwartz, N. L. (1982), *Market Structure and innovation.* Cambridge University Press: Cambridge.

Kanter, R., Kao, J. and Wierseman, F. (1997), *Innovation: Breakthrough ideas at 3M, Dupont, GE, Pfizer and Rubbermaid,* Harper Business: New York.

Kelly, D. and Amburgey, T. L. (1991), 'Organisational Inertia and Momentum: A Dynamic Model of Strategic Change', *Academy of Management Journal*, **34(3)**, 591-612.

Kimberly, J. R. and Evanisko, M. J. (1981), 'Organisational Innovation: The influence of individual, Organisational, and Contextual Factors on Hospital Adoption of Technological and Administrative Innovation', *Academy of Management Journal*, **24(4)**, 689-713.

Kline, S. J. and Rosenberg, N. (1986), 'An overview of innovation', in Landau, R. and Rosenberg, N. (eds.), *The Positive Sum Strategy,* National Academy Press: Washington DC.

Leiponen, A. and Drejer, I. (2007), ‘What exactly are technological regimes?: Intra-industry heterogeneity in the organisation of innovation activities’, *Research Policy,* **36(8)**, 1221-1238.

Leiponen, A. and Helfat, C. (2010), ‘Innovation objectives, knowledge sources, and the benefits of breadth’, *Strategic Management Journal*, **31**, 224-236.

Leonard-Barton, D. (1995), *Wellsprings of Knowledge: Building and sustaining the sources of innovation.* Harvard Business School Press: Massachusetts.

Lucas, R. E. (1988), ‘On the Mechanics of Economic Development’, *Journal of Monetary Economics,* **22**, 3-42.

Lundvall, B. –Å. (1992), *National Systems of Innovation – Towards a theory of innovation and interactive learning,* Pinter: London.

Malerba, F. (2004), ‘Sectoral Systems: How and Why Innovation Differs Across Sectors’, in Fagerberg, J., Mowery, D.C. and Nelson, R.R. (Eds.), *The Oxford Handbook of Innovation*, Oxford University Press: Oxford.

Malerba, F. and Orsenigo, L. (1999), ‘Technological entry, exit and survival: an empirical analysis of patent data’, *Research Policy,* **28(6)**, 643-660.

Mansfield, E. (1961), ‘Technical change and the rate of imitation’, *Econometrica,* **29(4)**, 741-766.

Mansfield, E. (1968), *Industrial research and technological innovation.* Norton: New York.

Mansfield, E. (1985), ‘How rapidly does new industrial technology leak out?’, *Journal of Industrial Economics,* **34**, 217-223.

Mansfield, E., Schwartz, M. and Wagner, S. (1981), ‘Imitation costs and patents: an empirical study’, *Economic Journal,* **91**, 907-18.

March, J. (1991), 'Exploration and Exploitation in Organisational Learning', *Organisation Science*, **2**, 71-87.

March, J. G. and Shapira, Z. (1992), 'Variable risk preferences and the focus of attention', *Psychological Review,* **99**, 172-183.

March, J. G. and Simon, H. A. (1958), *Organisations.* Wiley: New York.

Martin, B. and Irvine, J. (1983), 'Assessing basic research: some partial indicators of scientific progress in radio astronomy', *Research Policy*, **12**, 61-90.

Metcalfe, J. S. (1998), *Evolutionary Economics and Creative Destruction.* Routledge: London.

Metcalfe, J. S. (2007), 'Alfred Marshall and the General Theory of Evolutionary Economics', *History of Economic Ideas,* **15(1)**, 81-110.

Metcalfe, J. S. and Georghiou, L. (1998), 'Equilibrium and Evolutionary Foundations of Technology Policy', in OECD, *Science, Technology and Industry Review,* OECD: Paris.

Metcalfe, J. S. and Miles, I. (2000), *Innovation System in the Service Economy: Measurement and Case Study Analysis*, Kluwer: Massachusetts.

Miles, I. (2004), 'Innovation in services', in Fagerberg, J., Mowery, D. and Nelson, R. (eds.), *The Oxford Handbook of Innovation*, Oxford University Press: Oxford.

Milgrom, P. and Roberts, J. (1990), 'The Economics of Modern Manufacturing: Technology, Strategy, and Organisation', *American Economic Review,* **80(3)**, 551-528.

Mohr, L. B. (1969), 'Determinants of Innovation in Organisations', *the American Political Science Review*, **63(1)**, 111-126.

Nelson, R. R. (1959), 'The simple economics of basic scientific research', *Journal of Political Economy,* **67**, 297-306.

Nelson, R. R. (1991), ‘Why do firms differ, and how does it matter?’, *Strategic Management Journal*, **12**, 61-74.

Nelson, R. R. (1993), *National Innovation Systems: a comparative study.* Oxford University Press: Oxford.

Nelson, R. R. and Winter, S. G. (1982), *An Evolutionary Theory of Economic Change*, Harvard University Press: Massachusetts.

Nonaka, I. and Takeuchi, H. (1995), *The knowledge-creating company: How Japanese companies create the dynamics of innovation.* Oxford University Press: New York.

OECD (1996), *Employment and growth in the knowledge-based economy*. OECD: Paris.

OECD (2005), *Oslo Manual: guidelines for collecting and interpreting innovation data.* OECD: Paris.

OECD (2007), *Economic Surveys: Norway.* OECD: Paris.

Pavitt, K. (1984), ‘Sectoral patterns of technical change: towards a taxonomy and a theory’, *Research Policy,* **13(6)**, 343-373.

Penrose, E. T. (1959), *The Theory of the Growth of the Firm,* Blackwell: New York.

Peters, B. (2009), ‘Persistence of innovation: stylised facts and panel data evidence’, *Journal of Technology Transfer,* **34(2)**, 226-243.

Pettigrew, A. M. and Fenton, E. M. (2000), *The Innovating Organisation*. SAGE: London.

Porter, M. E. (1980), *Competitive Strategy: Techniques for analysing industries and competitors*. The Free Press: New York.

Powell, W. W., Koput, K. and Smith-Doerr, L. (1996), ‘Inter-organisational learning and the locus of innovation: Networks learning in biotechnology’, *Administrative Science Quarterly,* **41**, 116-145.

Prahalad, C. and Hamel, G. (1990), ‘The core competence of the corporation’, *Harvard business review,* **90(3)**, 79-91.

Raymond, W., Mohnen, P., Palm, F. and van der Loeff, S. S. (2006), ‘Persistence of innovation in Dutch manufacturing: is it spurious?’, CESifo Working Paper No. 1681.

Reedijk, J. (1998), ‘Sense and nonsense of science citation analyses: comments on the monopoly position of ISI and citation inaccuracies. Risks of possible misuse and biased citation and impact data’, *New journal of chemistry,* **22(8)**, 767-770.

Rogers, E. M. (1962), *Diffusion of innovations.* The Free Press: New York.

Rogers, M. (2004), ‘Networks, firm size and innovation’, *Small Business Economics,* **22(2)**, 141-153.

Romanelli, E. and Tushman, M. L. (1994), ‘Organisational Transformation as Punctuated Equilibrium: An Empirical Test’, *Academy of Management Journal*, **37(5)**, 1141-1166.

Romer, P. (1990), ‘Endogenous Technological Change’, *Journal of Political Economy,* **98**, S71-102.

Rosenberg, N. (1982), *Inside the black box.* Cambridge University Press: Cambridge.

Rothwell, R., Freeman, C., Horlsey, A., Jervis, V., Robertson, A. and Townsend, J. (1974), ‘SAPPHO Updated – project SAPPHO Phase II’, *Research Policy,* **3(3)**, 258-91.

Scherer, F. M. (1980), *Industrial market structure and economic performance.* Rand McNally: Chicago.

Schmookler, J. (1966), *Invention and Economic Growth.* Harvard University Press: Massachusetts.

Schumpeter, J. (1911), *The Theory of Economic Development*, Harvard University Press: Massachusetts.

Schumpeter, J. (1939), *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*, 2 volumes. McGraw-Hill: New York.

Schumpeter, J. (1942), *Capitalism, Socialism and Democracy*. Routledge: London.

Senge, P. (1990), *The fifth discipline: the art and practice of the learning organisation,* Doubleday: New York.

Simkin, M. and Roychowdhury, V. (2006), 'Do you sincerely want to be cited? Or: read before you cite', *Significance,* **3(4)**, 179-181.

Smith, K. (2004), 'Measuring Innovation', in Fagerberg, J., Mowery, D. and Nelson, R. (eds.), *The Oxford Handbook of Innovation*, Oxford University Press: Oxford.

Srholec, M. and Verspagen, B. (2008), 'The Voyage of the Beagle in Innovation Systems Land: Exploration on Sectors, Innovation, Heterogeneity and Selection', TIK Working Papers on Innovation Studies, Centre for Technology Innovation and Culture, University of Oslo.

Teece, D. (1986), 'Profiting from technological innovation: implications for integration, collaboration licensing and public policy', *Research Policy,* **15**, 285-305.

Teece, D. and Pisano, G. (1998), 'The dynamic capabilities of firms: an introduction', in Dosi, G., Teece, D., Chytry, J. (eds.), *Technology, Organisation and Competitiveness: Perspectives on Industrial and Corporate Change*, Oxford University Press: Oxford.

Teece, D. J., Pisano, G. and Shuen, A. (1997), 'Dynamic capabilities and strategic management', *Strategic Management Journal,* **18(7)**, 509-533.

Tidd, J., Bessant, J. and Pavitt, K. (2005), *Managing Innovation: Integrating Technological, Market and Organisational Change,* 3rd edition. Wiley: West Sussex.

Tushman, M. L. and Rosenkopf, L. (1992), ‘Organisational determinants of technological change: towards a sociology of technological evolution’, *Research in Organisational Behaviour,* **14**, 311-347.

von Hippel, E. (1988), *The sources of innovation,* Oxford University Press: New York.

Wernerfelt, B. (1984), ‘A resource-based view of the firm’, *Strategic Management Journal,* **5(2)**, 171-180.

Chapter 2

INNOVATION: EXPLORING THE KNOWLEDGE BASE[1]

Abstract

The need for knowledge may change with changes in society. New types of knowledge, and new ways of organising the production of it may emerge as knowledge producers respond to the challenges posed by a changing society. This study will focus on the core knowledge of one such emerging field, namely, innovation studies, i.e. the attempt to understand the social process which enables the continuation of qualitative improvements of products, technologies, and the organisation of economic activities. It is argued that this study may not only be relevant to those who want to know more about this specific field, but also to those interested in the wider question of how social science renews itself in response to a changing society. This chapter will describe the process which led to identifying the core literature in innovation studies. It will then analyse the characteristics of this literature, both in terms of thematic priorities and the background and orientation of the contributors. A subsequent step will involve searching for references to this core literature in scholarly journals and, with the help of a cluster analysis, these will be used to make inferences about how the field is structured, and its links with different disciplinary and cross-disciplinary contexts.

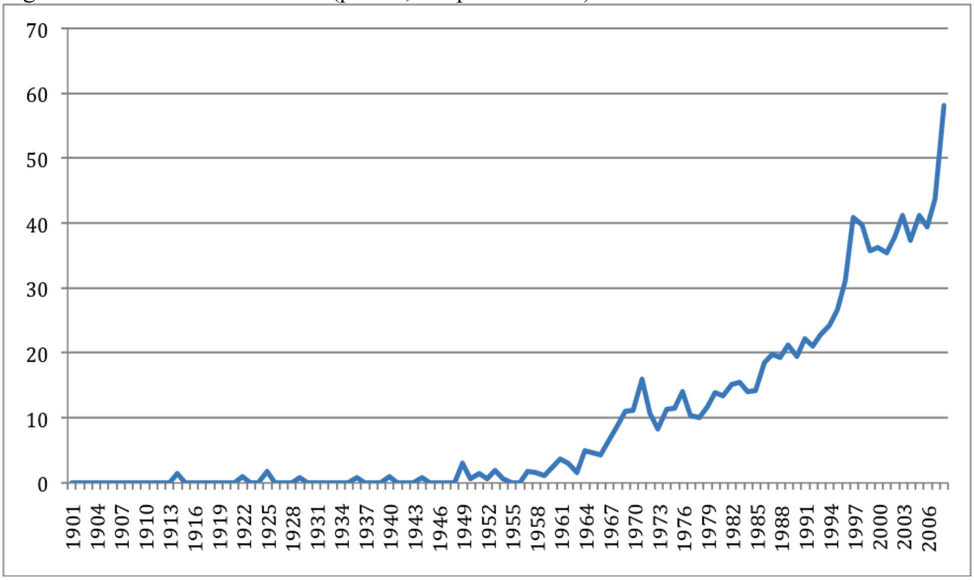
[1] This co-authored work with Jan Fagerberg benefits greatly from discussions with Ben Martin, Bart Verspagen and Paul Nightingale, amongst others.

1. Introduction

The need for knowledge may change with changes in society. New types of knowledge, and new ways of organising the production of it, may emerge as knowledge producers respond to the challenges posed by a changing society. In fact, the existing disciplines within the social sciences are themselves (relatively recent) examples of how new knowledge fields emerge and gradually establish themselves within appropriate organisations and institutions (Merton, 1973). There is no reason to believe that the existing pattern of organisation in the social sciences represents the end of history in this respect. On the contrary, new scientific fields are emerging all the time, within and across existing disciplines (Becher and Trowler, 2001; Whitley, 2000). This study will focus on one such emerging field, namely, innovation studies, i.e. the attempt to understand the social process which enables the continuation of qualitative improvements of products, technologies, and the organisation of economic activities. The study will explore the cognitive characteristics of the field, its links to other areas of science, as well as possible challenges/future prospects. It is argued that this study may not only be relevant to those who want to know more about this specific field, but also to those interested in the wider question of how social science renews itself in response to a changing society.

The field of innovation studies has grown tremendously in recent years, and probably several thousand academics worldwide are currently working on these issues (Fagerberg and Verspagen, 2009). However, although innovation is a very fashionable topic today, this has not always been the case. In fact, back in the early part of the previous century, at a time when the present social sciences were in an emergent state, very little attention was paid to the subject. Exceptions that prove the role include Gabriel Tarde (1903), a French judge who became interested in imitation and developed an original approach to the study of the subject, and Joseph Schumpeter (1911, 1942), who advanced a theory in which innovations, and the social agents underpinning them, were seen to be the driving forces of economic development. The topic received more attention around the time of the Second World War, when policy makers, first in the US and then elsewhere, became interested in R&D and innovation as an important impetus to progress in the military and, (to a lesser extent) the civil sector (Godin, 2006; Hounshell, 2000). However, it was not until the 1960s, half a century after Schumpeter first presented his theory and a decade after his death, that there was a real surge of interest in the subject. During the course of a few years, several important contributions emerged within different disciplines.[2] The very first cross-disciplinary research centre on the topic, SPRU at the University of Sussex, was established in 1966, to be followed by many others.[3] Research in this area has flourished since the 1960s, with a particularly strong growth in the 1990s (Figure 1). Several specialised journals[4] and professional societies[5] of interest in this field have also emerged.

Figure 1. Innovation in the title (per 10,000 publications)



Note: Publications in English language with a string innovat* in the title as a share of 10,000 of all annual additions to the British Library Integrated Catalogue 1901-2008

As in other areas of science, one important way in which social science renews itself is by responding to the emergence of new "problems", pointing to the scarcity or lack of relevance of the knowledge received. Such challenges, especially when accompanied by new resources,

---

[2] This applies, for instance, to economics (Nelson, 1959; Schmookler, 1966), management (Burns and Stalker, 1961) and sociology (Rogers, 1962; Coleman et al., 1966).

[3] Through a web-search, Fagerberg and Verspagen (2009) identified more than a hundred such research centres or departments worldwide within the social sciences, more than eighty percent of which were located in universities.

[4] Almost one thousand respondents to a survey of researchers in the field carried out by Fagerberg and Verpagen (2009) identified the following five journals as "the best outlet for work on innovation studies": Research Policy (RP), Industrial and Corporate Change (ICC), Journal of Evolutionary Economics (JEE), Journal of the Economics of Innovation and New Technology (EINT) and Structural Change and Economic Dynamics (SCED). It is worth noting that all but one (Research Policy) are of fairly recent origin (started during the 1990s).

[5] The most important are the International Joseph Schumpeter Society, founded in 1986, and the Technology and Innovation Management Division (TIM) of the (American) Academy of Management, from 1987.

may attract researchers from a variety of backgrounds and lead to the creation of new research communities, with institutions and organisations designed to promote scientific progress in the field. Such institutional and organisational features may be of great help when exploring the cognitive characteristics of a field, because they make it easier to identify the most important contributions and contributors. For example, in their study of the field of Strategic Management, Hambrick and Chen (2008) were able to identify the central contributions/contributors to that field because it was organised around a society and a journal (Strategic Management Society and Strategic Management Journal). However, the degree of institutionalisation and organisation may vary a great deal across different fields. Although, as mentioned, some professional meeting places have also emerged for Innovation Studies, there is no society which maps the entire field (Fagerberg and Verspagen, 2009). Furthermore, while the journal Research Policy[6] is generally acknowledged to be an important publishing outlet for this type of work, there is also a sprinkling of other publication channels which are made use of by researchers in this area. Thus, it may be necessary to look elsewhere for ways in which to identify the central scholarly contributions and, therefore, the cognitive characteristics of the field.[7]

A different way of studying the cognitive characteristics of a field, which may be more applicable to the present case, consists of identifying the core contributions by means of expert assessments (Crane, 1969, 1972). This case exploits the fact that a number of authoritative contributions surveying the field or important parts of it already exist, often published in the form of so-called "handbooks". It seems reasonable to assume that the authors of these surveys include references to the most important scholarly contributions of relevance to their topics (Crane, 1969). Although the topics of these surveys will differ somewhat, as may the references, some contributions may be referred to many times simply because they are considered to be particularly central, i.e. they represent the core knowledge

---

[6] In 1972, Christopher Freeman, the first director of SPRU, also founded Research Policy, the first specialised journal focusing on R&D and innovation.

[7] This is why Fagerberg and Verspagen (2009) felt compelled to collect their own data by means of a self-selecting "snowball" survey. Their study identified a large number of relatively small research groups bound together by a smaller number of what they called "cognitive communities", that is, networks of (groups of) scholars bound together by a common appreciation of central scholars in the field (sources of inspiration), common meeting places, and journals. However, it is possible that, by only including scholars who identified themselves with the term "innovation studies", the study overlooked researchers who work on innovation in contexts where the term is less common.

of the field. It will be assumed, therefore, that the subset of references which are referred to many times by different experts constitutes the core contribution in this area.

The structure of this chapter is as follows. The next section provides a detailed description of the process which led to the identification of the core literature in this area. The characteristics of this literature are then analysed, both in terms of thematic priorities and the background and orientation of the contributors. Subsequently, references to this core literature are taken from scholarly journals, and with the help of a cluster analysis, these are used to infer the structure of the field and its links with different disciplinary and cross-disciplinary contexts. The final section summarises the lessons learned from the study.

2. Innovation: Identifying the "core" literature

A search of highly regarded reference works (handbooks, textbooks) related to innovation was undertaken. Six of them, which contained a total of 181 chapters surveying various aspects of innovation, were chosen. These six were selected because they were published by high quality publishers, gave a reasonably balanced presentation of the field and satisfied certain criteria in respect of referencing.[8] The book by Dosi et al (1988) aims to present a relatively complete state-of-the-art overview of the subject as it was in the 1980s with, as the title indicates, a leaning towards economics. Although this was not called a "handbook" at the time, had it been published today, it may well have been given that label. The orientation toward economics is something it shares with the later volume by Stoneman (1995). In contrast, Dodgson and Rothwell (1994) and Fagerberg et al. (2004) have a more explicit cross-disciplinary profile. The same is true of the book by Shavinina (2003) which, however, also has a stronger focus on business and management than those mentioned so far. This focus is shared by a highly regarded textbook by Tidd et al. (2005), on the management of innovation.[9]

[8] Some of the 181 chapters were co-authored, so there were 213 authors in total. An attempt was made ex-post to check for the centrality of these authors in the field of innovation studies by investigating the extent to which they were editors, or served on the editorial boards/scientific committees of central journals in this field around 1995 and/or 2009. Ten journals were selected for this test, the five "most important" from the survey by Fagerberg and Verspagen (2009) and another five from the top journals citing the core literature (among the top ten citing journals in Table 4 those with the highest impact factors were selected). In the case of Dosi et al. (1988), 62% of the authors had such journal affiliations, while the remaining, with one exception (Shavinina, 2003), were within the 28 – 39 % range. This result is deemed to be quite satisfactory. However, in the case of Shavinina (2003), the similar number was only 6%, and this calls for caution. Therefore, a sensitivity test for the inclusion of the references from Shavinina (2003) in the sample will be reported below.

Table 1. Reference works (11,288 references)

Name of author/editor	Title	Year of publication	Publisher	Number of chapters (references)
G. Dosi et al	Technical Change and Economic Theory	1988	Pinter	27 (1,336)
M. Dodgson & R. Rothwell	Handbook of Industrial Innovation	1994	Elgar	35(1,247)
P. Stoneman	Handbook of the Economics of Innovation and Technological Change	1995	Blackwell	13 (1,630)
L. Shavinina	International Handbook on Innovation	2003	Elsevier	71 (4,303)
J. Fagerberg et al.	The Oxford Handbook of Innovation	2004	Oxford	22 (1,688)
J. Tidd et al.	Managing Innovation	2005(3rd ed.)	Wiley	13 (1,084)

As a next step, all of the references in these books, chapter by chapter, were collected and put together in a database.[10] After the references had been cleaned (for errors of various kinds), 11,288 remained, about 8,100 of which were non-identical, and most of these (92.7 percent) were only mentioned once or twice. The fact that the publications referred to by these references were published at different times implies that the older titles may have a greater chance of being cited than those published more recently. In order to provide a fairer comparison of how many times a set of publications is referred to, the statistics which correct for this difference were calculated (the J-index).[11] This study focuses on the most commonly cited ones which are assumed to be of the greatest general importance. The cut off rate was set at 3.3%, which means that any publication which was cited less than once per thirty

[9] On the publisher's website Professor Clayton M. Christensen of Harvard Business School, author of the "The Innovator's Dilemma" (ranked no. 3 in the list of core innovation literature, see Table 2 below), writes: "This is an extraordinary synthesis of the most important things that are understood about innovation, written by some of the world's foremost scholars in this field." (http://www.wiley.co.uk/wileychi/innovate/).

[10] Gratitude must be given to Joe Tidd, Larissa Shavinina and Paul Stoneman for supplying the references in the books for which they were responsible in a machine-readable format and to Ad Notten at UNU-MERIT for helping to scan some of the remainder.

[11] Define maximum citations (E) for any paper or book (B) as one citation per chapter in any source (i.e. 181 chapters in total) published at least one year after the publication of B. If actual citations are A, then the share A*100/E was used as a citation count (J-index).

chapters (which could potentially have cited it) was not included in the "core literature". The retained sample consisted of 147 publications (see Appendix A for details).[12]

The J-index reflects how important a publication is within broadly defined innovation studies (according to experts in this area). However, its importance may not be limited to this specific field, but may extend to other specialisations and disciplines. In order to ascertain to what extent this is the case, citations to the core literature in journals included in the Web of Science (ISI – Thomson) were sought, and a staggering number came to light, around 129 thousand citations, more than eight hundred per publication on average.

Table 2 lists the twenty most important contributions to innovation studies based on the 181 assessments (handbook chapters) included in this study. The name and location of authors, title, publication type, year, J-index and the number of citations per year in the Web of Science are reported for each of these top twenty contributions. Taken together, these contributions cover a wide range of topics relevant to innovation. Some are theoretical in nature, such as Schumpeter's "The Theory of Economic Development", originally published in 1911 in German and then revised in an English edition in 1934 (number 4 on the list). Many of the ideas, concepts and definitions used today stem from this classic text. However, in the view of experts (i.e. based on the J-index), an even more important theoretical contribution is "An Evolutionary Theory of Economic Change" from 1982 by the Americans Nelson and Winter (number 1 on the list), which combines Schumpeterian and evolutionary perspectives with insights obtained from more theories on organisations and human behaviour. Other top-ranked contributions present synthetic overviews and interpretations of current knowledge of innovation, either generally (Freeman's "The Economics of Industrial Innovation", no. 2 on the list), or selected aspects (Roger's "Diffusion of Innovation", no 7 on the list) or contexts (Christensen's "The Innovators dilemma", no. 3 on the list). A number of highly ranked contributions focus on new concepts or frameworks of analysis and/or their application. For example, this is true of Lundvall's and Nelson's contribution on "national systems of innovation" (no. 5 and no. 8 on the list), Dosi's "technological paradigms and trajectories" (no. 10) and Pavitt's "sectoral taxonomy" (no. 11).

[12] For the above reasons, the sensitivity of excluding the references from Shavinina (2003) from the sample was tested. Of the top twenty contributions reported in table 2, seventeen - 85 % - remained in the top twenty after the exclusion of the references from Shavinina (2003). For the whole set of 147 references, the correlation coefficient between the J-indexes with and without the references from Shavinina was 0.89. This is taken as an indication that the picture presented here is pretty robust to the selection of sources.

Table 2. Innovation: Top Twenty Contributions

No	Author	Country	Title	Type	Year	J-index	Citations (ISI/Year)
1	Nelson RR; Winter SG	USA	An Evolutionary Theory of Economic Change	Book	1982	23.8	165.0
2	Freeman C	UK	The Economics of Industrial Innovation	Book	1974	18.8	30.4
3	Christensen CM	USA	The Innovator's Dilemma	Book	1997	16.0	88.4
4	Schumpeter JA	Austria	The Theory of Economic Development	Book	1911	16.0	55.2
5	Nelson RR	USA	National Innovation Systems	Book	1993	15.6	61.0
6	Leonard-Barton D	USA	Wellsprings of Knowledge	Book	1995	14.2	51.2
7	Rogers EM	USA	Diffusion of Innovations	Book	1962	13.8	204.3
8	Lundvall B	Denmark	National systems of innovation	Book	1992	13.6	59.3
9	Porter ME	USA	The Competitive Advantage of Nations	Book	1990	13.6	166.9
10	Dosi G	UK	Technological paradigms and technological trajectories	Journal (RP)	1982	13.3	29.7
11	Pavitt K	UK	Sectoral patterns of technical change	Journal (RP)	1984	13.3	23.2
12	Tidd J; Bessant JR; Pavitt K	UK	Managing Innovation	Book	1997	13.2	25.6
13	von Hippel E	USA	The Sources of Innovation	Book	1987	12.7	50.0
14	Schumpeter JA	USA	Capitalism, Socialism, and Democracy	Book	1942	12.2	79.7
15	Nonaka I; Takeuchi H	Japan	The Knowledge-Creating Company	Book	1995	11.3	176.0
16	Rosenberg N	USA	Inside the Black Box	Book	1982	11.0	37.1
17	Henderson RM; Clark KB	USA	Architectural Innovation	Journal (ASQ)	1990	10.4	49.2
18	Rothwell R	UK	Successful Industrial Innovation	Journal (R&D Man.)	1992	10.4	9.5
19	Freeman C	UK	Technology Policy and Economic Performance: Lessons from Japan	Book	1987	9.9	20.2
20	van de Ven et al.	USA	The Innovation Journey	Book	1999	9.4	15.0

Note: Since the SSCI backfile starts from 1956, ISI/year for the publications prior to this year (Schumpeter 1911, 1942) was calculated as total ISI citations over the number of years from 1956 to 2008.

What clearly emerges from this table is the strong American performance. More than half of the top twenty contributions are American, and this is also true of the larger sample from which the top twenty are taken. However, perhaps what strikes the eye even more is that eighty percent of these top ranked publications are books, and if the analysis is extended to include the whole sample of publications, although the share of journal articles rises somewhat, to close to forty percent, the majority are still books (see Appendix A). One interpretation of this finding is that it confirms the immature (emerging) nature of the field (Konrad and Pfeffer, 1990; Pfeffer, 1993). However, it may also be that the book format, with its scope for a more holistic analysis, plays a more important role in social sciences than is commonly assumed, although there is currently no empirical evidence to offer advice on this.[13]

The final column to the right reports the number of citations in journals per year of these contributions (Web of Science). Although many of the entries are highly cited, there is not a particularly high correlation between the assessments by the experts, as reflected in the J-index, and the number of citations from the Web of Science. This is neither surprising nor worrying. The J-index reflects the importance of the various contributions to the field of innovation studies as assessed by experts in this particular field. However, the number of citations in the Web of Science reflects the impact or popularity of the work in question in the more general world of science. There is no reason to expect these to match. A good example is Thomas Kuhn's outstanding work "The Structure of Scientific Revolutions", which has had more than four hundred citations per year since publication, which is a truly staggering number (see Appendix A). However, this primarily reflects its importance for a whole range of disciplines/fields, extending far beyond social science proper, and has little or nothing to do with its role within innovation studies. In fact, its influence is rather modest in the latter field (no. 60 on the list with a J-index of 5). Thus, its impact is clearly much more strongly felt outside innovation studies (which explains the exceptionally high number of citations in the Web of Science).

Influential contributors typically publish several important works, often in cooperation with others, and this needs to be taken into account when attempting to identify the most important

[13] This may well have to do with the fact that the most commonly used database on the subject, that of ISI Thomson, makes it much more difficult (though not altogether impossible) to search for citations to books than (selected) journals.

contributors. For example, while most authors in the sample have one publication which fits the threshold for inclusion in the core literature, five of them have contributed between six and eight publications each, either alone or in cooperation with others. Table 3 ranks the top ten scholars in this area on the basis of their total contributions, how those contributions were assessed by the experts, and adjusted for co-authorship. The "Total J-index" is the (co-author adjusted) sum of the J-indices of an author's works (a similar calculation is used for "Total ISI/Year", which refers to citations in the Web of Science). When judged by this criterion, four contributors stand out as being particularly influential, namely, Freeman, Nelson, Rosenberg[14] and Schumpeter, followed at a distance, by Pavitt, Dosi and Lundvall.

Table 3. Innovation: Top 20 contributors

Rank	Authors	Affiliation(s)	Country	Total J-index	Total ISI/year
1	Freeman C	SPRU	UK	42.0	76.8
2	Nelson RR	Columbia/Yale/RAND	USA	40.6	172.9
3	Rosenberg N	Stanford	USA	40.2	97.4
4	Schumpeter JA	Harvard/Graz	USA/ Austria	34.3	157.3
5	Pavitt K	SPRU	UK	25.4	40.8
6	Dosi G	SPRU	UK	24.0	74.1
7	Lundvall B	Aalborg/OECD	Denmark/ France	23.8	84.2
8	Mansfield E	U Penn.	USA	16.8	49.1
9	Perez C	SPRU	UK	16.6	21.9
10	Winter SG	Yale	USA	16.2	96.9
11	Christensen CM	Harvard/Graz	USA	16.0	88.4
12	Rothwell R	SPRU	UK	16.0	14.9
13	Teece DJ	Berkeley	USA	16.0	105.9
14	Griliches Z	Harvard	USA	15.5	80.9
15	Leonard-Barton D	Harvard	USA	14.2	51.2
16	Rogers EM	Ohio State U.	USA	13.8	204.3
17	Porter ME	Harvard	USA	13.6	166.9
18	Hamel G	LBS	UK	13.4	102.8
19	von Hippel E	MIT	USA	12.7	50.1
20	Williamson OE	U Penn./Yale	USA	12.7	170.9

Note: Since the SSCI backfile starts from 1956, total ISI/year for Schumpeter is the sum of total ISI/year of his three books (1911, 1939, 1942), which was calculated as total ISI citations over the number of years from 1956 to 2008 (see Appendix A).

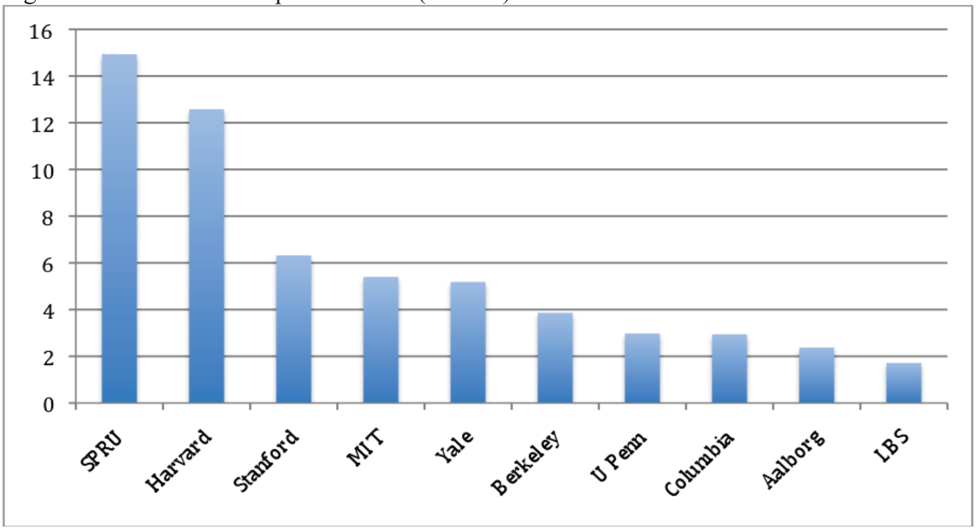
Ranking scholars is a risky business. However, it is reassuring that the web-based worldwide survey of more than one thousand researchers within "innovation studies" (Fagerberg and

[14] The high position of the US economic historian, Nathan Rosenberg, may seem surprising given that he has no work among the top ten. However, the explanation is that he is the most productive of all authors on the list with eight publications above the threshold for inclusion in the core literature.

Verspagen, 2009) points to exactly the same seven scholars as being the most important "sources of inspiration" for scholarly work in this area. It can hardly be a coincidence that two investigations into the same issue, based on totally different data and methods, lead to almost the same result.

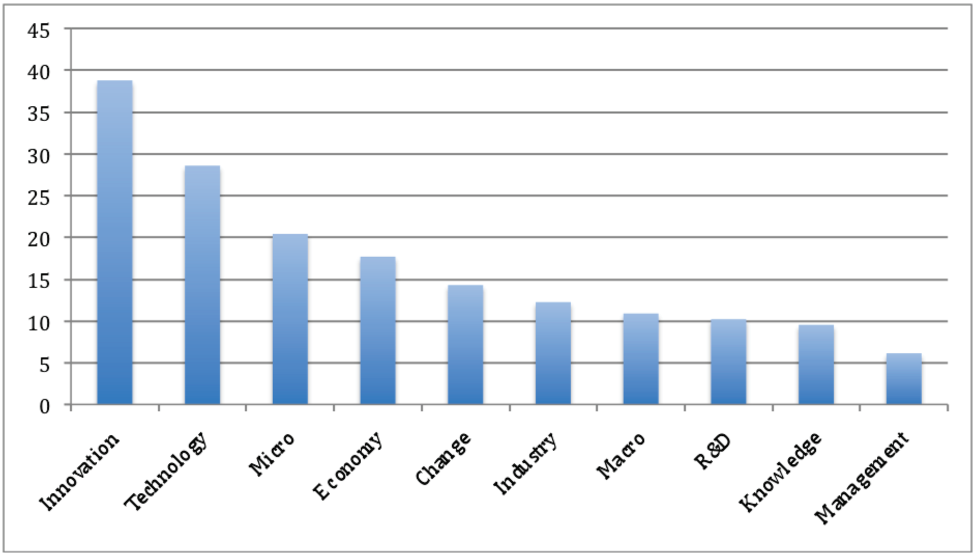
Figure 2 ranks the ten top research institutions in this area based on the scientific contributions of their employees and the importance of these contributions as assessed by experts (the J-index). The calculation shows that SPRU (Science Policy Research Unit, University of Sussex, UK), home to such influential scholars as Freeman, Pavitt and (at some point) Dosi, is well ahead of the others. The second to the seventh place following SPRU are all occupied by prestigious US universities (headed by Harvard), while the next European institution on the list, in the eighth place far below SPRU, is Aalborg University, home to the scholar Bengt Åke Lundvall, who, among other things, has done much to propagate the "national system of innovation" approach (Lundvall, 1992).

Figure 2. Innovation – Top Institutions (J-index)



Another way to characterise this emerging knowledge base is to examine the thematic priorities. It would have been preferable to analyse this by means of a text analysis of abstracts but the core literature mainly consists of books (which do not have abstracts), so this was not an option. In fact, most of the journal articles, especially the older ones, did not have abstracts either. Therefore, the titles were chosen for analysis, with a focus on commonly used terms, or “keywords”. The titles were divided into words, and the number of times a specific word appeared was counted. Similar words, such as “economic”, “economy” etc. were grouped together, while commonly used, but uninteresting, words such as “and” or “why” were excluded. As was perhaps to be expected, the most common keyword was “innovation”. Figure 3 illustrates that 39% of the core publications have innovation in the title. “Technology” is another commonly used term, shared by 29% of the contributions. As for the level of analysis, the firm level (“micro”) was clearly the most popular. 20% have “firm” (or corporation) in the title, far more than, say, “industry” (12%) or the regional, national or global level (“macro”), which accounted for 11%.

Figure 3. Thematic focus, percentage



3. Innovation: Knowledge users

In the previous section, the core contributions to the field have been identified, but this has been almost entirely from an “insider’s view”, i.e. the view of a set of established experts within the field. This section will move from the knowledge producers, and the experts assessing their work, to the users of this knowledge. How can these be identified? It is fortunate that the use of scientific knowledge leaves trails, for instance in the form of citations, and these will be exploited here. A search was made for citations to the full sample of 147 contributions in the scholarly journals included in the Web of Science (ISI Thomson), and a note was made of the scientific fields of these journals, as reflected in the so-called subject-areas,[15] of which there were more than two hundred. In this way, it was possible to make a connection between each citation and one or more scientific field (a journal may cover several subject-areas). By taking all citations to a particular contribution into account, a quantitative assessment may be obtained of how this contribution is used by scholars in different scientific fields and/or disciplines.

Table 4. Knowledge users: Top twenty Journals

Rank	Journal	Percent	Cumulative Percent	Subject-area(s)
1	Research Policy	4.0	4.0	Management; Planning & Development
2	Strategic Management Journal	2.1	6.1	Business; Management
3	International Journal of Technology Management	1.8	7.9	Engineering, Multidisciplinary; Management; Operations Research & Management Science
4	Technovation	1.5	9.4	Engineering, Industrial; Management; Operations Research & Management Science
5	Technological Forecasting and Social Change	1.2	10.6	Business; Planning & Development
6	R and D Management	1.1	11.7	Business; Management
7	Journal of Management Studies	1.1	12.7	Business; Management
8	Organisation Science	1.1	13.8	Management
9	Academy of Management Review	1.0	14.8	Business; Management
10	Technology Analysis and Strategic Management	.9	15.7	Management; Multidisciplinary Sciences
11	Journal of Product Innovation Management	.9	16.5	Business; Engineering, Industrial; Management
12	Management Science	.8	17.4	Management; Operations Research & Management Science
13	Regional Studies	.8	18.2	Environmental Studies; Geography
14	Organisation Studies	.8	19.0	Management
15	Academy of Management Journal	.8	19.8	Business; Management
16	Industrial and Corporate Change	.8	20.6	Business; Economics; Management
17	IEEE Transactions on Engineering Management	.7	21.3	Business; Engineering, Industrial; Management
18	Cambridge Journal of Economics	.7	22.0	Economics
19	Journal of Evolutionary Economics	.6	22.6	Economics
20	Administrative Science Quarterly	.6	23.2	Business; Management

A total of around 6,000 journals (in all areas of science) cited this literature. However, most of them cited very little, i.e. one citation per year or less. 10% of the journals contained three quarters of the citations. Table 4 below lists the 20 most important citing journals, which

[15] ISI categorises journals, and hence articles, based on subject-area(s), which may be disciplines or "specialisms" within or across disciplines.

collectively account for about one quarter of all citations. As is evident from the table, authors in Research Policy are especially eager users of this literature, representing twice as high a share as the next entry on the list, Strategic Management Journal. Many of the top citing journals belong to the fields of management and business, which indicates that scholars in management and business studies are important users of this knowledge. Nonetheless, the list of top journals also includes a journal which focuses on regional issues and, toward the end of the top twenty, two (heterodox) economics journals. It is worth noting that, although many of the top scholars in this area have a background in economics (Fagerberg and Verspagen, 2009), mainstream economics journals do not appear to be among the prime users of this literature.

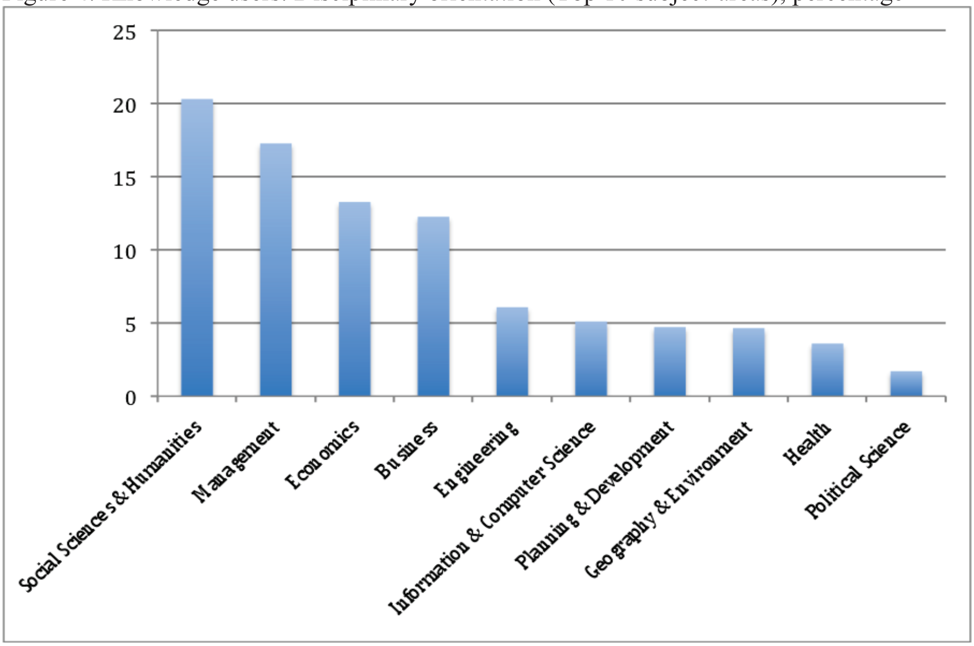
Although taking note of the top journals is quite illustrative, a more precise description of the disciplinary orientation of the knowledge users in this area may be obtained by using the approach described above, i.e. to take account of the information about subject-area categories. However, it should be noted that the subject-area categories, of which there are several hundred, have been developed by ISI over the years, and do not always cover disciplines or scientific fields (within or across disciplines) in a way which is appropriate for this research. For example, the extent to which specialities within, or across, disciplines are covered varies greatly, and relatively recent, although vibrant, fields, such as innovation studies, may not be covered at all.[16] In some cases the subject-areas are fairly aggregated (economics for instance), while in others, a discipline may be divided into many different categories (psychology may serve as example of this). For the purpose of this research, it would be useful if the subject-areas could be aggregated into a smaller number of groups of like-minded scholars, and in order to approach this objective, the most obvious adjustments were made (first), such as merging all the different subgroups within psychology into one group. However, even after this merger, nearly two hundred different areas remained.

This research, therefore, opted to look more closely at the citation patterns of the 35 biggest subject-areas (those with 500 citations or more each), which altogether accounted for more than 90 % of the total citations to the core literature, to determine whether or not some of these could be meaningfully aggregated into larger wholes. Particular attention was paid to

[16] Thus, journals focusing on a novel area such as innovation studies, to the extent that such journals are included at all, will have to be found in other categories. For example, the quite ill-defined “planning and development” category is home to Research Policy, the most important journal in this area.

how scholars in the different subject-areas used the core literature in innovation studies, and if the citation patterns (preferences) of two subject-areas were strongly correlated, this was taken as an argument for merging the two. Similarly, if the patterns turned out to be rather different, this was seen as a reason for keeping them apart. The results of this analysis (see Appendix B) indicate that, while some disciplines or scientific fields, such as economics, political science and "planning and development" have rather distinct citation profiles, these differences are almost negligible in other cases. In this way, it was possible to identify a large group of like-minded users in disciplines such as education, psychology, philosophy and sociology, which was aggregated into a common "Social sciences and humanities" group. Similarly, this grouping exercise found a cluster of (strongly related) scientific fields focusing on health, and another which incorporated information and computer science, as well as a third which emphasised spatial issues (urban studies geography and environmental studies).[17] Figure 4 provides an illustration of how the users are divided across the ten largest groups, which collectively account for 89% of the total citations to the core literature in the Web of Science.

Figure 4. Knowledge users: Disciplinary orientation (Top 10 subject-areas), percentage



[17] Readers interested in more details may consult Appendix B to this chapter.

Figure 4 confirms that the core literature is used in a broad array of disciplines and scientific fields. The composite "Social sciences and humanities" group is the largest, with 20% of the users, and this is followed by Management (17%), Economics (13%) and Business (12%).[18] Together the latter three areas, which all focus on economic activities in one way or another, account for almost one half of the total number users. There are also many users in other areas of social science (not included in the larger composite), the largest of which is the cross-disciplinary "Planning and Development" field, home to Research Policy and some other important journals in this area. Although the overwhelming number of users (close to ninety percent) is within social sciences (broadly defined), there is also a significant number in areas such as engineering and natural science.

Figure 5. Knowledge users: Where they work

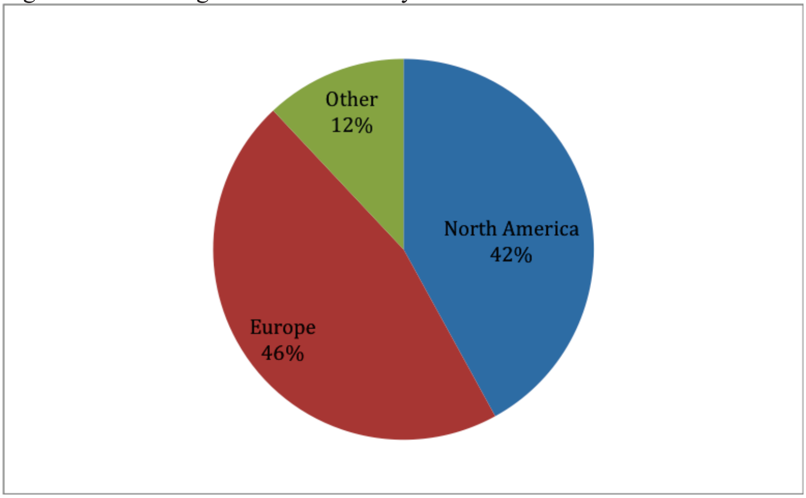


Figure 5 attempts to shed light on the geographical composition of the knowledge users. Unfortunately, the data does not allow for a complete analysis of authors and their locations, since much of this information is missing, especially for the years prior to 1998 and for multi-authored papers. Therefore, the figure is based on a subset of 28,917 single-authored papers published after 1997.[19] For what it is worth, Figure 5 shows that the largest group of users is

[18] It is sometimes suggested that such numbers may reflect differences in citation intensity between fields. This was, therefore, checked (Figure B2 in Appendix B), and the results indicate that, if such differences were adjusted for, Management, Economics and Business would be of about the same size (14-15%). The strongest increase would be observed for Engineering, and Information and Computer Science (but not enough to alter the ranking).

[19] Although there is no reason to believe that the locations of authors of single-authored papers deviate in a systematic way from those of other authors, lack of information of earlier years means that it is not possible to

to be found in Europe, closely followed by North America and, at a distance, the rest of the world. That innovation studies is largely a European-American affair, with Europe as the largest hub, is consistent with the results from the web-based survey of innovation scholars conducted by Fagerberg and Verspagen (2009).[20]

4. Exploring the structure of the knowledge base

This section will provide an in-depth exploration into the cognitive characteristics of the field, and its relationship with the scientific world at large. This is undertaken in the form of a cluster analysis of the core literature, which draws on evidence from the two previous sections. The analysis particularly focuses on three dimensions of this evidence: the *thematic orientation* of the core literature, its *disciplinary orientation* (as assessed by the users) and various characteristics of the literature in respect of the *generation and selection processes* which take place.

In terms of the thematic character of the core literature, the occurrence of "key-words" reflecting the orientation of the contribution towards various issues is used (the ten most commonly used terms were selected, see Figure 3 above). The value 1 is assigned to a keyword variable if the contribution has the respective keyword in the title. In terms of the disciplinary profiles of these contributions, the ten most important subject-areas or groups are similarly used (Figure 4). This variable is measured as the share of citations from a particular subject-area in all citations to the contribution. As for the production and selection environments, a number of variables (five in total) are used. These variables are elaborations of the information presented in the previous sections. Firstly, the analysis includes a variable which reflects the orientation of the contribution in respect of innovation studies proper compared to the scientific world in general (INSIDER). This variable, which is the ratio of the J-index to journal-citations (ISI) per year, is high if the contribution is considered to be more relevant in innovation studies than elsewhere, and vice versa.[21] The analysis also includes a variable to measure the quality of the research environment with which the author(s) of the various contributions were affiliated (at the time of publication), with the assumption that this

explore changes which may have occurred in the geographic spread of the knowledge users during the period covered by this study.

[20] However, the division between Europe and North-America appears to be more even than that indicated by Fagerberg and Verspagen (2009).

[21] A small positive value (0.0256) was added to the denominator to avoid problems caused by values for ISI/year (range-standardised) close to zero.

may influence both the quality of the contribution and the probability of its inclusion in the core literature. This variable (EXCELLENCE) is measured as the sum of the J-indices of all publications in the core literature emanating from that particular research environment (adjusted for co-authorship). Since one research environment (SPRU) appears to be much more productive than the others, and has played an important role in the development of the field, a separate effect from being affiliated with that is allowed.[22] The analysis also considers that some journals, such as Research Policy and Strategic Management Journal, are very prestigious, and that citations from such sources may signal particularly high quality and/or relevance. These variables (RP and SMJ) are calculated as the share of citations from articles published in Research Policy and Strategic Management Journal, respectively, in all citations to the contribution.

A cluster analysis is an exploratory tool which sorts similar objects into the same group (cluster), so that the degree of association between objects is maximal if these belong to the same group, and minimal otherwise. Hence, the purpose of a cluster analysis is primarily to explore structures in the data. Various methods are available, but not all of these allow for a mix of continuous and categorical variables in the analysis as is required in the present case. The Two-step cluster method in SPSS (version 11.5 and later) fulfils this requirement, and was, therefore, chosen for the analysis. As the name suggests, this method has two steps. In the first step, the objects are aggregated into a large number of small clusters, and in the second step, these clusters are merged into a limited number of larger clusters by means of agglomerative hierarchical clustering. According to traditional statistical criteria,[23] the three best cluster solutions are the ones with two, three, and four clusters (see Appendix C for details). It should be noted that, due to the hierarchical clustering method, the two and three cluster solutions are mere aggregations of the four cluster solution. Since this research is interested in an in-depth analysis of the structure reflected in the data, the most detailed of these three solutions is described in the following paragraphs (see Table 5).

[22] The SPRU variable equals one if all of the authors of a publication were affiliated with SPRU at the time of publication. If the authors had different affiliations, the number is fractionalised.

[23] Various criteria are available. This study reports the BIC (Schwarz Bayesian Information Criterion) and Ratio of Distance Measures (see Appendix C for details). It should be noted, however, that a cluster analysis is an explorative method, and, as pointed out by Hair et al. (2010:515), the informed judgement of the researcher is essential when deciding the number of clusters.

Table 5. Clustering the literature

Cluster	**Core Innovation Studies**	**Economics & Technology**	**Outsiders**	**Innovation Management**
Works (authors)	28 (23)	56 (59)	29 (47)	34 (57)
Thematic focus	Innovation (75%) Technology (36%)	Technology (39%) Economy (34%)	Firms (52%) Innovation (21%)	Innovation (76%) Firms (38%)
Most central work (J-index)	Freeman 1974	Nelson and Winter 1982	Nonaka and Takeuchi 1995	Christensen 1997
Most cited work (ISI/year)	Nelson 1993	Porter 1990	Kuhn 1962	Rogers 1962
Most important affiliation	SPRU (57%)	Harvard (21%) Stanford (12%)	MIT (9%) Berkeley (7%)	Harvard (17%) SPRU (15%)
Location of authors	Europe (77%) North America (21%)	North America (75%) Europe (24%)	North America (67%) Europe (25%)	North America (64%) Europe (35%)
Most important citing journal	Research Policy	Research Policy	Strategic Management Journal	Research Policy
Largest citing field	Management (21%) Economics (16%)	Economics (29%) Social Sciences & Humanities (16%)	Social Sciences & Humanities (30%) Management (16%)	Management (25%) Business (18%)
Specialisation	Planning and development	Economics	Social Sciences & Humanities / Information & Computer Science	Management / Business / Engineering
Location of citers	Europe (66%) North America (20%)	Europe (45%) North America (44%)	North America (52%) Europe (37%)	North America (50%) Europe (38%)
Insider (normalised mean 0-1)	0.36	0.15	0.06	0.24
Excellence (normalised mean 0-1)	0.65	0.32	0.13	0.38

Clearly, the largest cluster, consisting of 56 contributions, focuses to a large extent on issues related to “Economics and Technology”, which is also the name chosen for this cluster. The contributors to this literature are mainly Americans, working in top US universities, while the users of this knowledge are much more evenly distributed geographically (close to the sample average). The largest citing field is Economics, and the most central work, as assessed by the experts (the J-index), is Nelson and Winter's "An Evolutionary Theory of Economic Change" published in 1982, which is normally regarded as being very heterodox (and is cited much more outside economics than within).[24] Hence, the term "economics" does not necessarily imply a signal that this literature is mainstream. For example, there are four economics journals among the ten most important journals citing this cluster, of which only one is clearly mainstream (American Economic Review), while two are more heterodox (Cambridge Journal of Economics and Journal of Evolutionary Economics).[25]

The second largest cluster consists of 34 works united by a strong focus on innovation in firms. In fact, more than three quarters of the contributions in this category have the term "innovation" in the title. As in the previous case, the knowledge users are fairly geographically widespread, while the producers are predominately Americans. The largest citing field is Management (followed by Business), and the most central work is Christensen's "The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail" published in 1997, a topical book from management literature. Another characteristic feature of this literature is that all of the most important journals which cite it have Management or Business among their subject-areas. Therefore, the name "Innovation Management" was chosen for this cluster.

The two remaining clusters are approximately equal in size, but otherwise, they are quite different. The cluster called "Core Innovation Studies" (28 works) also focuses very strongly on innovation (three quarters of the works in this category have "innovation" in the title) and, like the largest cluster mentioned above, on "technology". In contrast to the previous cases, the knowledge producers in this cluster are predominantly Europeans. In fact, more than half of the contributors had a SPRU affiliation at the time of publication, so this cluster is clearly centred on SPRU, the oldest and most prestigious specialised research environment in this area. It is perhaps no surprise that the most central work in this literature was written by

[24] According to Meyer (2001), Nelson and Winter's book has many more citations in management and organisational science journals than in economics journals. The likelihood of a citation was six times higher in the Strategic Management Journal than in the American Economic Review.

[25] Another economics journal of the four is Small Business Economics, which focuses mainly on entrepreneurship and small businesses.

Christopher Freeman, the founder of the SPRU. What may be surprising is that, in this case, not only the knowledge producers, but also the knowledge users, are mainly Europeans. The largest citing field is, as in the previous case, Management, closely followed by Economics, and Planning and development. However, in relative terms, when differences in the size of citing fields are adjusted for, it is the latter field which contributes most to differentiating this from the other clusters. The cluster also has a very high "insider" index, which indicates that this literature is much more appreciated by experts in this specific field than by the scientific world at large.

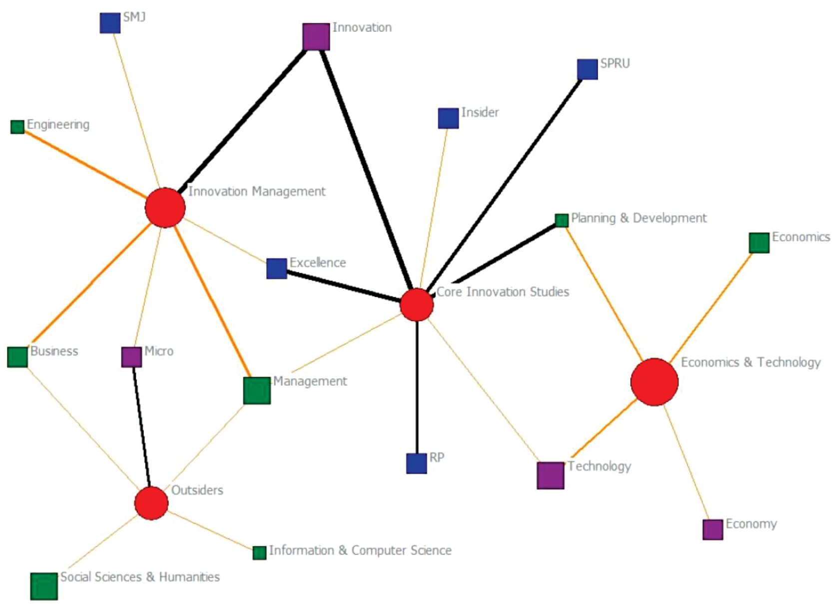
Finally, there is a cluster with 29 contributions, which has been labelled "Outsiders". This label has been chosen partly because the thematic focus in this case is more on firms in general than, say, their technological activities or innovative performances. However, it also has to do with the fact that, while they are highly cited in the Web of Science (ISI/year), many works in this cluster are much less central to the particular field being studied here (as reflected in the J-index). As previously mentioned, the most typical example of this pattern is Thomas Kuhn's book "The Structure of Scientific Revolutions", published in 1962. This is reflected in a record low "insider" index (close to zero) for this cluster, which confirms that, on the whole, this literature is much more orientated to other disciplines and scientific fields. Another characteristic feature which contributes to differentiating this cluster from the others is that the most important citing field in this case is the composite "Social sciences and humanities" group. In fact, the majority of citations from Social sciences and humanities were made to the literature in this cluster.

Figure 6 summarises some of the above information in the form of a network graph.[26] The literature clusters are shown as circles of various sizes, depending on the number of works in the cluster, and the variables taken into account in the cluster analysis are treated as being possible links between clusters. For example, if two literature clusters share a thematic focus (keyword), this constitutes a link between the two. In the cluster analysis, the numerical value of these variables was normalised to a range between zero and unity, with unity indicating a very strong connection, and zero no connection at all. Since there will always be a certain amount of variety of the characteristics within a cluster, there will normally be many weak links (close to zero), and a smaller number of stronger links indicating the existence of more

[26] This network graph was produced using a spring-embedding method in Ucinet/Netdraw. The input data source is the results of the cluster analysis (the four cluster case, see Appendix C).

robust relationships between the cluster and the variables. If all links are taken into account, independent of their strength, all clusters will appear to be closely connected. However, when the weaker, not so important, links are removed, a clearer structure may emerge. This is why the weaker, not so typical links, have been eliminated in Figure 6, and the focus has been placed on the more significant ones (by setting the "cut-off" rate to one third in the zero-unity range).

Figure 6. Relationships between literature clusters and variables (cut off = 0.33)



Note: Literature clusters are denoted by red circles of different sizes, based on the number of works in the cluster (see Table 5). Disciplinary orientation variables are denoted by green squares of different sizes, based on the amount of citations to the 147 core innovation literature from the (composite) subject-area concerned (see Figure 4). Thematic orientation variables are denoted by purple squares of different sizes, based on the share of the 147 core innovation literature that have the keyword concerned in the title (see Figure 3). Blue squares (all of the same size) represent the remaining variables, which include Insider, Excellence, SPRU, RP and SMJ. The strength of the relationships between the clusters and the variables is indicated by line thickness and colour (strong and medium links are in black and orange colours, respectively).

As shown in Figure 6, the cluster called "Core Innovation Studies" lives up to its name. Compared to the other clusters, it has much stronger links with the most central academic institution (SPRU), the strongest journal (Research Policy), the most productive research environments (Excellence), and so on. More importantly, the central finding from the figure is that this cluster is also “core” in a more fundamental sense: its knowledge (and those who produce it) constitutes a link between the “Economics & Technology” and the “Innovation Management” and “Outsiders” clusters. Without this the entire knowledge base would fragment into an economics part and a management/outsider part with little, if anything, in common.

Another way to illustrate the integrative role played by “Core Innovation Studies” is to examine the overlap in authorship between the three literature clusters.[27] As mentioned, some prolific writers contributed several works, and sometimes also to more than one cluster.[28] However, there were big differences between the four clusters in this respect. While, in the “Core Innovation Studies”, 61% of the authors had also contributed to the other literature clusters, the similar shares for the authors of the other clusters were much lower, from 13% (“Outsiders”) to 21-22% in the two remaining cases.

5. Concluding remarks

A century ago the innovation theorist, Joseph Schumpeter, reflecting the state of social science, pointed out that “individual social sciences ... did not arise through the logical division of some originally unified realm of knowledge; they arose by chance ... from some particular problem or method” (Schumpeter, 1910/2003, as cited in Andersen, 2009:312). From this perspective social sciences should be analysed as being an evolving structure, constantly challenged by new problems and the need for new knowledge. However, such evolutionary processes are often slow to materialise and easy to lose track of. Therefore, an observer of social science at a particular point in time may be forgiven for thinking that the structure, with disciplines, journals, associations, departments etc, has been pretty stable. Yet, it is boiling beneath the surface! New scientific fields or specialisations, within or across disciplines, are emerging all the time in response to problems which arise and the need for new knowledge. In fact, many, if not most, of the several hundred “subject-areas” which exist in the Web of Science are related to the rise of such fields or specialisations within, but increasingly also across, established disciplines.

[27] Detailed statistics not reported here, but available upon request.

[28] Most overlaps included no more than two clusters. In fact, only two authors were present in three clusters, one of which was Christopher Freeman.

Since such emerging areas of knowledge usually lack most of the institutions and organisations which characterise established disciplines, they may be difficult to study, and this is also true of the field under scrutiny here, i.e. innovation studies. When confronted by this challenge, the present study chose to follow in the footsteps of Crane (1969, 1972) and others, and study the characteristics of the field through the eyes of experts. Having identified the core contributors and contributions to the field in this way, and analysed their characteristics, this knowledge was complemented by a collection of information about the users of this literature (as reflected in citations in scholarly journals). In this way, it was possible to throw some light on the nature of the relationship between the emerging field of innovation studies and other currents (including the established disciplines) within the world of science.

This study demonstrates that a sizeable amount of literature on innovation has been developed, primarily from the 1960s onwards, with a particularly strong growth during the last period covered. Thus, although innovation is not at all a new phenomenon, societal interest in it is clearly much larger now compared with a few decades or half a century ago. In response to this change, researchers from a variety of backgrounds took up the challenge and, as a result, a broad knowledge base for innovation studies, as viewed from different angles and perspectives, has emerged. The production of this knowledge has been particularly strong in the US and the UK. The position of the latter in this field is, to a large extent, related to the emergence in the 1960s of the Science Policy Research Unit (SPRU) at the University of Sussex, and the academic entrepreneurship of Christopher Freeman, who is the single most important contributor to innovation literature, according to the assessments of experts in this area. In this connection, it is worth mentioning that the most central contributors according to this study are the same as those identified by a previous survey (Fagerberg and Verspagen, 2009) using different data and methods. This strengthens the validity of the results presented here.

Although the central literature in this area is mainly produced by scholars from the US and the UK, with affiliations to a limited number of strong research environments in those countries, the users of this literature are much more geographically widespread. Moreover, the disciplinary orientation of these users, as it is revealed based on the subject-areas of journals in which their works are published, clearly emphasises the multi-disciplinary and cross-disciplinary characteristics of the field, with users within a whole range of disciplines and fields extending far beyond social science proper. Surprising to some, perhaps, only one of seven users is an economist in the accepted meaning of the term. It deserves to be mentioned, though, that there are many users in related fields who also focus on economic matters in some sense or another. This includes fields such as management, business, planning and development, geography etc. Therefore, in this broader sense, the share of "economics" users would be larger, close to one half of the sample. Such a perspective on economics would be consistent with the views of Schumpeter, who argued in favour of a very broad definition of the subject (Andersen, 2009).

Arguably, the main value added of the research presented here consists of the analysis of the cognitive focus of the literature which has emerged, the links between the different parts of this literature, and the relationship with the rest of the scientific world. Basically, what has been demonstrated is that there are two main "poles" in innovation literature, one of which focuses on innovation in firms, and is popular with scholars in business and management, and another which emphasises the role played by technology and innovation in economic and social change more generally. The latter is particularly appreciated by scholars with a background in economics, economic geography etc. However, a more detailed analysis reveals that it is possible to distinguish a third branch of research which is positioned in between the two main poles, and which contributes significantly to keeping the different parts of the knowledge base connected. This branch, which has been called "Core Innovation Studies", consists of literature which is very central according to experts in this area, is cited a great deal in the most important journal (Research Policy), and has a strong connection to the most central research environment (SPRU). As pointed out earlier, without this research, the entire knowledge base would fragment into an economics and a management orientated part with few, if any, links.

From a systems point of view, the cross-disciplinary research conducted within "Core Innovation Studies" performs a very important (integrative) function, and it would be interesting to explore in more detail the role academic entrepreneurs played in this area, for example, Christopher Freeman. Arguably, the future prospects for this scientific field may depend, to a large extent, on this (integrating) function also being performed in the years to come. An important question for further research is whether this can be achieved in the same way as before, or whether it will require a stronger institutional and organisational structure. It would also be interesting to compare the development of innovation studies with other emerging scientific fields to see how such integration have been conducted there. Perhaps there are some general lessons for the evolution of (social) science to be learned.

References

Andersen, E. S. (2009), *Schumpeter's evolutionary economics. A Theoretical, Historical and Statistical Analysis of the Engine of Capitalism*. Anthem: London.

Becher, T. and Trowler, P. (2001), *Academic Tribes and Territories: Intellectual Enquiry and the Culture of Discipline*, 2nd edition, Open University Press: Buckingham.

Burns, T. and Stalker, G. (1961), *The management of innovation*. Tavistock: London.

Christensen, C. M. (1997), *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail.* Harvard Business School Press: Massachusetts.

Coleman, J. S., Katz, E. and Menzel, H. (1966), *Medical Innovation.* Boobs-Merril: New York.

Crane, D. (1969), 'Social Structure in a Group of Scientists: A Test of the "Invisible College"', *Hypothesis, American Sociological Review*, **34**, 335-352.

Crane, D. (1972), *Invisible Colleges: diffusion of knowledge in scientific communities*. University of Chicago Press: Chicago.

Dodgson, M. and Rothwell, R. (eds.) (1994), *Handbook of Industrial Innovation.* Edward Elgar: Aldershot.

Dosi, G. (1982), 'Technological paradigms and technological trajectories', *Research Policy*, **11**, 147-162.

Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L., (eds.) (1988), *Technical Change and Economic Theory*. Pinter: London

Fagerberg, J. and Verspagen, B. (2009), 'Innovation Studies – the emerging structure of a new scientific field', *Research Policy,* **38**, 218-233.

Fagerberg, J., Mowery, D. C. and Nelson, R. R. (eds.) (2004), *The Oxford Handbook of Innovation*. Oxford University Press: Oxford.

Freeman, C. (1974), *The Economics of Industrial Innovation*. Penguin: Harmondsworth.

Godin, B. (2006), 'The Linear Model of Innovation: The Historical Construction of an Analytic Framework', *Science, Technology & Human Values*, **31**, 631-667.

Hair, J. F., Black, W. C., Babin, B. J. and Anderson, R. E. (2010), *Multivariate Data Analysis*, 7th edition. Prentice Hall: New Jersey.

Hambrick, D. and Chen, M. (2008), 'New academic fields as admittance-seeking social movements: the case of Strategic Management', *Academy of Management Review*, **33**, 32-54.

Hounshell, D. (2000), 'Medium is the message, or how context matters: The RAND Corporation builds on economics of innovation, 1946-1962'. In Hughes, A. and Hughes, T. (eds.) *System, Experts, and Computers.* MIT Press: Massachusetts.

Konrad, A.M. and Pfeffer, J. (1990), 'Do You Get What You Deserve? Factors Affecting the Relationship between Productivity and Pay', *Administrative Science Quarterly*, **35**, 258-285.

Kuhn, T. (1962) *The Structure of Scientific Revolutions.* University of Chicago Press: Chicago.

Lundvall, B. Å. (1992), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Pinter: London.

Merton, R. K. (1973) *The Sociology of Science: Theoretical and Empirical Investigations*. University of Chicago Press: Chicago.

Meyer, M. (2001), 'Nelson and Winter's evolutionary theory – a citation analysis', paper presented at the DRUID's Nelson and Winter conference, Copenhagen.

Nelson, R. R. (1959), 'The simple economics of basic scientific research', *Journal of Political Economy*, **67**, 297-306.

Nelson, R. R. (ed.) (1993), *National Innovation Systems: A Comparative Study*. Oxford University Press: Oxford.

Nelson, R. R. and Winter, S. G. (1982), *An Evolutionary Theory of Economic Change*. Harvard University Press: Massachusetts.

Pavitt, K. (1984), 'Sectoral Patterns of Technical Change: Towards a Taxonomy and Theory', *Research Policy*, **13**, 343-73.

Pfeffer, J. (1993), 'Barriers to the Advance of Organizational Science: Paradigm Development as a Dependent Variable', *The Academic of Management Review*, **18**, 599-620.

Rogers, E. M. (1962) *Diffusion of innovations*. The Free Press: New York.

Schmookler, J. (1966) *Invention and Economic Growth*. Harvard University Press: Massachusetts.

Schumpeter, J. (1910/2003), 'How does one study social science', *Society*, **40**, 57-63

Schumpeter, J. (1911), *The Theory of Economic Development*. Harvard University Press: Massachusetts.

Schumpeter, J. (1942), *Capitalism, Socialism and Democracy*. Routledge: London.

Shavinina, L., (ed.) (2003), *International Handbook on Innovation*. Elsevier: Oxford.

Stoneman, P. (ed.) (1995), *Handbook of the Economics of Innovation and Technological Change*. Blackwell: Oxford.

Tarde, G. (1903). *The Laws of Imitation*. Henry, Holt and Co: New York.

Whitley, R. (2000), *The Intellectual and Social Organization of the Sciences*. Oxford University Press: Oxford.

Appendix A

Table A. Core innovation literature (ranked by J-index)

No.	Author	Country	Title	Type	Year	J-Index	ISI/ year	Cluster No.*
1	Nelson RR; Winter SG	USA	An Evolutionary Theory of Economic Change	Book	1982	23.8	165.0	2
2	Freeman C	UK	The Economics of Industrial Innovation	Book	1974	18.8	30.4	1
3	Christensen CM	USA	The Innovator's Dilemma	Book	1997	16.0	88.4	4
4	Schumpeter JA	Austria	The Theory of Economic Development	Book	1911	16.0	55.2	2
5	Nelson RR	USA	National Innovation Systems	Book	1993	15.6	61.0	1
6	Leonard-Barton D	USA	Wellsprings of Knowledge	Book	1995	14.2	51.2	4
7	Rogers EM	USA	Diffusion of Innovations	Book	1962	13.8	204.3	4
8	Lundvall B	Denmark	National systems of innovation	Book	1992	13.6	59.3	1
9	Porter ME	USA	The Competitive Advantage of Nations	Book	1990	13.6	166.9	2
10	Dosi G	UK	Technological paradigms and technological trajectories	Journal (RP)	1982	13.3	29.7	1
11	Pavitt K	UK	Sectoral patterns of technical change	Journal (RP)	1984	13.3	23.2	1
12	Tidd J; Bessant JR; Pavitt K	UK	Managing Innovation	Book	1997	13.2	25.6	4
13	von Hippel E	USA	The Sources of Innovation	Book	1987	12.7	50.0	4
14	Schumpeter JA	USA	Capitalism, Socialism, and Democracy	Book	1942	12.2	79.7	2
15	Nonaka I; Takeuchi H	Japan	The Knowledge-Creating Company	Book	1995	11.3	176.0	3
16	Rosenberg N	USA	Inside the Black Box	Book	1982	11.0	37.1	2
17	Henderson RM; Clark KB	USA	Architectural Innovation	Journal (ASQ)	1990	10.4	49.2	4
18	Rothwell R	UK	Successful Industrial Innovation	Journal (R&D Man.)	1992	10.4	9.5	1
19	Freeman C	UK	Technology Policy and Economic Performance: Lessons from Japan	Book	1987	9.9	20.2	1
20	Van de Ven et al.	USA	The Innovation Journey	Book	1999	9.4	15.0	4
21	Kline SJ; Rosenberg N	USA	An Overview of Innovation	Chapter	1986	9.4	15.0	1
22	Rosenberg N	USA	Perspectives on Technology	Book	1976	8.8	19.1	2

23	Hamel G	UK	Leading the Revolution	Book	2000	8.5	20.1	4
24	Lundvall B	Denmark	Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation	Chapter	1988	8.4	17.7	1
25	Teece DJ; Pisano G	USA	The Dynamic Capabilities of Firms: an Introduction	Journal	1994	8.4	18.3	4
26	Utterback JM	USA	Mastering the Dynamics of Innovation	Book	1994	8.4	42.1	4
27	Burns T; Stalker GM	UK	The management of innovation	Book	1961	8.3	55.7	3
28	Teece DJ	USA	Profiting from technological innovation: implications for integration, collaboration, licensing and public policy	Journal	1986	8.3	46.5	4
29	Cohen WM; Levinthal DA	USA	Absorptive capacity: A new perspective on learning and innovation	Journal	1990	7.8	124.3	4
30	Tushman ML; Anderson P	USA	Technological discontinuities and organisational environments	Journal	1986	7.7	42.6	4
31	Leifer R; McDermott CM; O'Connor GC; Peters LS; Rice MP; Veryzer RW	USA	Radical Innovation: How Mature Companies Can Outsmart Upstarts	Book	2000	7.5	10.6	4
32	Rothwell R; Freeman C; Horsley A; Jervis VTP; Robertson AB; Townsend J	UK	SAPPHO Updated: Project SAPPHO Phase II	Journal	1974	7.2	8.8	4
33	Clark KB; Fujimoto T	USA, Japan	Product development performance: strategy, organisation, and management in the world auto industry	Book	1991	7.1	53.9	4
34	Womack JP; Jones DT; Roos D	USA, UK	The machine that changed the world: based on the Massachusetts Institute of Technology 5-million dollar 5-year study on the future of the automobile	Book	1990	7.1	100.4	3

35	Freeman C; Clark J; Soete L	UK	Unemployment and Technical Innovation: A Study of Long Waves and Economic Development	Book	1982	6.6	11.1	1
36	Nelson RR; Winter SG	USA	In search of useful theory of innovation	Journal	1977	6.6	13.4	1
37	Schmookler J	USA	Invention and Economic Growth	Book	1966	6.6	19.0	2
38	Williamson OE	USA	Markets and hierarchies: analysis and antitrust implications: a study in the economics of internal organisation	Book	1975	6.6	168.8	3
39	Tushman M; O'Reilly CA	USA	Winning through innovation: a practical guide to leading organisational change and renewal	Book	1997	6.6	17.2	4
40	Cohen WM; Levinthal DA	US	Innovation and Learning: The Two Faces of R & D	Journal	1989	6.5	43.3	2
41	Mowery DC; Rosenberg N	USA	Technology and the Pursuit of Economic Growth	Book	1989	6.5	14.7	2
42	Arrow KJ	USA	Economic welfare and the allocation of resources for invention	Chapter	1962	6.1	26.0	2
43	Perez C	UK	Structural Change and Assimilation of New Technologies in the Economic and Social Systems	Journal	1983	6.1	6.1	1
44	Piore MJ; Sabel CF	USA	The second industrial divide: possibilities for prosperity	Book	1984	6.1	108.2	2
45	Schumpeter JA	USA	Business cycles: a theoretical, historical, and statistical analysis of the capitalist process	Book	1939	6.1	22.4	2
46	Williamson OE	USA	The economic institutions of capitalism: firms, markets, relational contracting	Book	1985	6.1	2.1	2
47	Hamel G; Prahalad CK	USA, UK	Competing for the Future	Book	1994	5.9	64.8	3
48	Saxenian A	USA	Regional Advantage: Culture and Competition in Silicon Valley and Route 128	Book	1994	5.9	87.3	2
49	Dosi G	UK	Sources, procedures and microeconomic effects of innovation	Journal	1988	5.8	31.3	1

50	Freeman C	UK	Networks of Innovators: A Synthesis of Research Issues	Journal	1991	5.8	11.7	1
51	Freeman C; Perez C	UK	Structural crises of adjustment: business cycles and investment behaviour	Chapter	1988	5.8	7.3	1
52	Dodgson M; Bessant JR	UK, Australia	Effective Innovation Policy: A New Approach	Book	1996	5.7	3.1	1
53	Garcia R; Calantone R	USA	A Critical Look at Technological Innovation Typology and Innovativeness Terminology: A Literature Review	Journal	2002	5.7	15.5	4
54	Cowan R; David PA; Foray D	USA, France, the Netherla nds	The explicit economics of knowledge codification and tacitness	Journal	2000	5.7	13.6	2
55	Abernathy WJ; Utterback JM	USA	Patterns of industrial innovation	Journal	1978	5.5	17.0	4
56	Vernon R	USA	International investment and international trade in the product cycle	Journal	1966	5.5	32.8	2
57	Chandler AD	USA	Scale and Scope: The Dynamics of Industrial Capitalism	Book	1990	5.2	57.2	2
58	Dosi G; Freeman C; Nelson R; Silverberg G; Soete L	USA, UK, the Netherla nds	Technical Change and Economic Theory	Book	1988	5.2	28.1	2
59	Romer PM	USA	Endogenous Technological Change	Journal	1990	5.2	98.0	2
60	Kuhn T	USA	The structure of scientific revolutions	Book	1962	5.0	402.5	3
61	Mansfield E; Schwartz M; Wagner S	USA	Imitation costs and patents: an empirical study	Journal	1981	5.0	9.4	2
62	Mowery DC; Rosenberg N	USA	The Influence of market demand upon innovation: A critical review of some recent empirical studies	Journal	1979	5.0	6.4	1
63	Pasinetti LL	Italy	Structural Change and Economic Growth: A Theoretical Essay on the Dynamics of the Wealth of Nations	Book	1981	5.0	7.6	2
64	Stoneman P	UK	The Economic Analysis of Technological	Book	1983	5.0	8.4	2

			Change					
65	Best M	USA	The new competitive advantage: technology management and regional growth dynamics	Book	2001	4.7	5.7	2
66	Foster RN; Kaplan S	USA	Creative destruction: why companies that are built to last underperform the market, and how to successfully transform them	Book	2001	4.7	9.7	3
67	Granstrand O; Patel P; Pavitt K	UK, Sweden	Multi-technology corporations: Why they have "distributed" rather than "distinctive core" competencies	Journal	1997	4.7	6.1	4
68	Grove AS	USA	Only the paranoid survive: how to exploit the crisis points that challenge every company	Book	1996	4.7	11.6	3
69	Mowery DC; Rosenberg N	USA	Paths of innovation: technological change in 20th century America	Book	1998	4.7	8.5	1
70	Sternberg RJ	USA	Handbook of Creativity	Book	1999	4.7	21.0	3
71	Teece DJ; Pisano G; Shuen A	USA	Dynamic capabilities and strategic management	Journal	1997	4.7	125.3	4
72	Wenger E	USA	Communities of practice: learning, meaning, and identity	Book	1998	4.7	163.1	3
73	Dodgson M	UK	Technological collaboration in industry: strategy, policy, and internationalisation in innovation	Book	1993	4.5	8.9	1
74	Griliches Z	USA	Patent Statistics as Economic Indicators: A Survey	Journal	1990	4.5	32.1	2
75	Jaffe A	USA	Real effects of academic research	Journal	1989	4.5	19.5	2
76	Wheelwright SC; Clark KB	USA	Revolutionizing product development: quantum leaps in speed, efficiency, and quality	Book	1992	4.5	37.6	4
77	Landes DS	USA	The Unbound Prometheus: Technological change and industrial development in Western Europe from 1750 to the	Book	1969	4.4	21.7	2

			present					
78	Fagerberg J	Norway	A Technology Gap Approach to Why Growth Rates Differ	Journal	1987	4.4	3.6	2
79	Griliches Z	USA	R&D, patents and productivity	Book	1984	4.4	13.6	2
80	Mensch G	Germany	Das technologische Patt: Innovationen überwinden die Depression (English: Stalemate in technology: innovations overcome the depression)	Book	1975	4.4	10.9	2
81	Nelson RR	USA	The simple economics of basic scientific research	Journal	1959	4.4	7.6	2
82	Rothwell R	UK	The Characteristics of Successful Innovators and Technically Progressive Firms (with some comments on innovation research)	Journal	1977	4.4	4.0	4
83	Rosenberg N	USA	Exploring the black box: technology, economics, and history	Book	1994	4.2	15.3	2
84	Amabile TM	USA	A model of creativity and innovation in organisations	Journal	1988	3.9	12.5	3
85	Mansfield E	USA	Academic research and industrial innovation	Journal	1991	3.9	10.8	1
86	Prahalad CK; Hamel G	USA, UK	The Core Competence of the Corporation	Journal	1990	3.9	100.6	4
87	Robson M; Townsend J; Pavitt K	UK	Sectoral patterns of production and use of innovations in the U.K.: 1945-1983	Journal	1988	3.9	1.9	1
88	Senge PM	USA	The fifth discipline: the art and practice of the learning organisation	Book	1990	3.9	194.2	3
89	Altschuler A; Anderson M; Jones D; Roos D; Womack J	USA, UK	The Future of the automobile: the report of MIT's International Automobile Program	Book	1984	3.9	6.0	2
90	Campbell DT	USA	Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes	Journal	1960	3.9	7.0	3
91	Coombs R; Saviotti P; Walsh V	UK	Economics and Technological Change	Book	1987	3.9	3.6	2
92	Dosi G	UK	Technical Change and Industrial Transformation	Book	1984	3.9	7.5	1

93	Drucker PF	USA	Innovation and entrepreneurship: practice and principles	Book	1985	3.9	21.9	3
94	Levin RC; Klevorick AK; Nelson RR; Winter SG	USA	Appropriating the returns from industrial research and development	Journal	1987	3.9	30.6	2
95	Mansfield E	USA	Industrial research and technological innovation: an econometric analysis	Book	1968	3.9	15.7	2
96	Mansfield E; Rapoport J; Schnee J; Wagner S; Hamburger M	USA	Research and innovation in the modern corporation	Book	1971	3.9	7.3	2
97	Penrose ET	UK	The Theory of the Growth of the Firm	Book	1959	3.9	43.8	3
98	Perez C	UK	Microelectronics, Long Waves and the World Structural Change: New Perspectives for Developing Countries	Journal	1985	3.9	4.3	1
99	Polanyi M	UK	The Tacit Dimension	Book	1966	3.9	49.5	3
100	Posner MV	UK	International trade and technical change	Journal	1961	3.9	4.0	2
101	Sahal D	Germany	Patterns of Technological Innovation	Book	1981	3.9	9.8	4
102	Scherer FM	USA	Inter-industry technology flows in the United States	Journal	1982	3.9	3.2	2
103	Solow RM	USA	Technical change and the aggregate production function	Journal	1957	3.9	30.6	2
104	Brown S; Lamming R; Bessant J; Jones P	UK	Strategic Operations Management	Book	2000	3.8	0.6	3
105	Brusoni S; Prencipe A; Pavitt K	UK	Knowledge specialisation, organisational coupling, and the boundaries of the firm: Why do firms know more than they make?	Journal	2001	3.8	11.9	4
106	Chesbrough HW; Teece DJ	USA	When is Virtual Virtuous	Journal	1996	3.8	16.9	4
107	Cooper RG	Canada	From experience: The invisible success factors in product innovation	Journal	1999	3.8	5.9	4
108	De Geus A	UK	The Living Company	Book	1997	3.8	10.5	3

109	Edquist C	Sweden	Systems of innovation: technologies, institutions and organisations	Book	1997	3.8	34.1	1
110	Kanter RM; Kao J; Wiersema F	USA, UK	Innovation: Breakthrough thinking at 3M, DuPont, GE, Pfizer, and Rubbermaid	Book	1997	3.8	1.6	4
111	Landes DS	USA	The Wealth and Poverty of Nations: Why Some are so Rich and Some so Poor	Book	1998	3.8	43.0	2
112	Oliver N; Blakeborough M	UK	Innovation networks: the view from the inside	Chapter	1998	3.8	0.4	1
113	Patel P; Pavitt K	UK	The wide (and increasing) spread of technological competencies in the world's largest firms: a challenge to conventional wisdom	Chapter	1998	3.8	1.5	4
114	Perez C	UK	Technological Revolutions and Financial Capital: the dynamics of bubbles and golden ages	Book	2002	3.8	7.8	1
115	Shapiro C; Varian HR	USA	Information Rules: A strategic guide to the network economy	Book	1998	3.8	75.2	3
116	Trott P	UK	Innovation Management and New Product Development	Book	1998	3.8	2.9	4
117	Weick KE	USA	Sense-making in Organisations	Book	1995	3.8	114.0	3
118	Bryson B	UK	Made in America: an informal history of the English language in the United States	Book	1994	3.4	1.1	3
119	Gibbons M; Limoges C; Schwartzman S; Nowotny H; Trow M; Scott P	USA, UK, Austria, Canada, Brazil	The New Production of Knowledge, the Dynamics of Science and Research in Contemporary Societies	Book	1994	3.4	81.0	3
120	Lundvall B; Johnson B	Denmark, France	The learning economy	Journal	1994	3.4	14.5	2
121	Patel P; Pavitt K	UK	National Innovation Systems: Why They Are Important, And How They Might Be Measured And Compared	Journal	1994	3.4	3.4	1
122	Wolfe RA	Canada	Organisational	Journal	1994	3.4	9.4	3

			innovation: Review, critique and suggested research directions					
123	Argyris C; Schön DA	USA	Organisational learning: A theory of action perspective	Book	1978	3.3	63.1	3
124	Arrow KJ	USA	The economic implications of learning by doing	Journal	1962	3.3	26.4	2
125	Carter CF; Williams BR	UK	Industry and technical progress: factors governing the speed of application of science	Book	1957	3.3	4.1	2
126	Cooper RG	Canada	Winning at New Products	Book	1986	3.3	18.0	4
127	David PA	USA	Clio and the Economics of QWERTY	Journal	1985	3.3	33.5	2
128	Griliches Z	USA	Issues in Assessing the Contribution of Research and Development to Productivity Growth	Journal	1979	3.3	16.4	2
129	Kanter RM	USA	The change masters: Innovations for productivity in the American corporation	Book	1983	3.3	50.3	3
130	Langrish J; Gibbons M; Evans W; Jevons F	UK	Wealth from Knowledge: A Study of Innovation in Industry	Book	1972	3.3	5.9	4
131	Levin RC; Cohen WM; Mowery DC	USA	R&D appropriability, opportunity, and market structure: new evidence on some Schumpeterian hypotheses'	Journal	1985	3.3	4.3	2
132	Mansfield E	USA	Technical Change and the Rate of Imitation	Journal	1961	3.3	10.7	2
133	Mansfield E	USA	How rapidly does new industrial technology leak out?	Journal	1985	3.3	7.3	2
134	Metcalfe JS	UK	Impulse and diffusion in the study of technical change	Journal	1981	3.3	2.0	2
135	Mowery DC	USA	The relationship between intra-firm and contractual forms of industrial research in American manufacturing, 1900–1940	Journal	1983	3.3	3.2	2
136	Nelson RR	USA	A Diffusion model of international productivity differences in manufacturing	Journal	1968	3.3	1.8	2

			industry					
137	Rosenberg N	USA	Science, Invention and Economic Growth	Journal	1974	3.3	2.2	2
138	Salter WEG	Australia	Productivity and Technical Change	Book	1960	3.3	11.5	2
139	Kotler P	USA	Marketing Management: Analysis, Planning, and Control	Book	1967	3.3	56.5	3
140	Barras R	UK	Interactive innovation in financial and business services: the vanguard of the service revolution	Journal	1990	3.2	2.9	1
141	Carlsson B; Stankiewicz R	USA, Sweden	On the Nature, Function, and Composition of Technological Systems	Journal	1991	3.2	7.7	2
142	Fagerberg J	Norway	International competitiveness	Journal	1988	3.2	4.6	2
143	Griliches Z	USA	The search for R&D spillovers	Journal	1992	3.2	18.8	2
144	Hounshell DA; Smith JK	USA	Science and Corporate Strategy: Dupont R&D, 1902-1980	Book	1988	3.2	7.9	3
145	Lamming R	UK	Beyond Partnership: Strategies for Innovation and Lean Supply	Book	1993	3.2	16.9	4
146	Nonaka I	Japan	The knowledge creating company	Journal	1991	3.2	32.9	3
147	Roussel PA; Saad KN; Erickson TJ	USA	Third generation R&D: managing the link to corporate strategy	Book	1991	3.2	13.3	3

*Cluster 1 = Core Innovation Studies, Cluster 2 = Economics and Technology, Cluster 3 = Outsiders, Cluster 4 = Innovation Management.

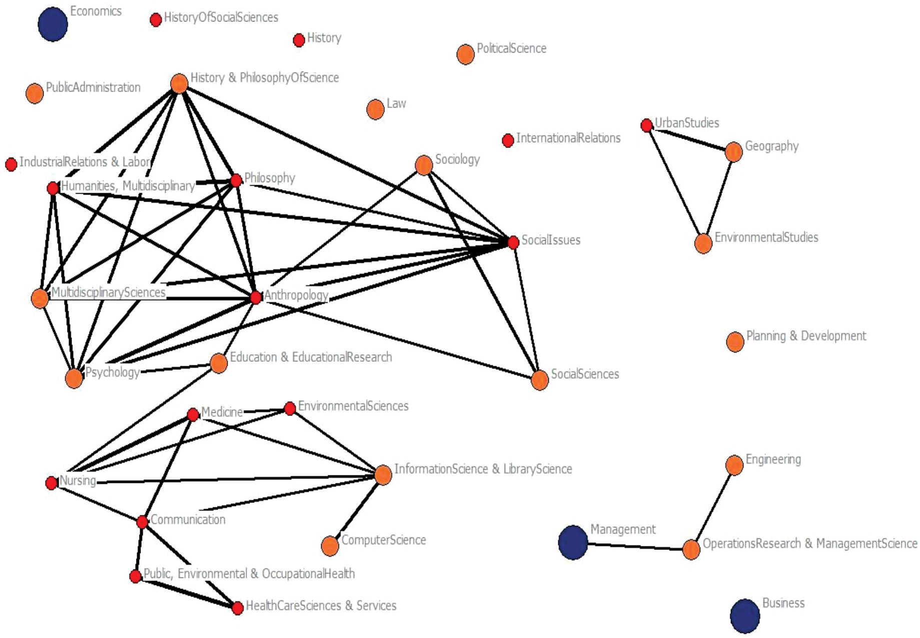
Note: Since the SSCI backfile starts from 1956, ISI/year for the publications prior to this year (Schumpeter 1911, 1939, 1942) was calculated as total ISI citations over the number of years from 1956 to 2008.

Appendix B

Table B. Subject-areas (with number of citations to the core innovation literature > 500) and sub-categories

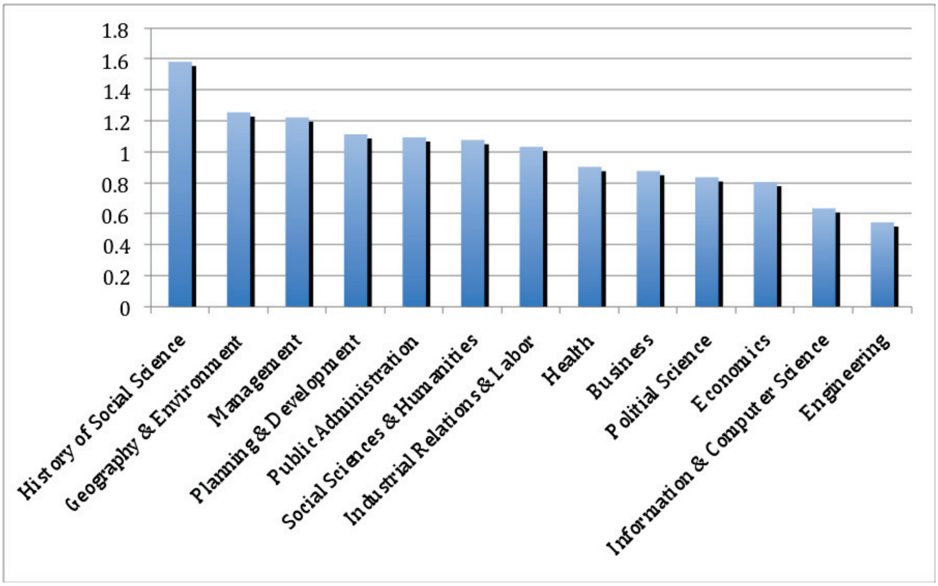
Subject-areas	No. of citations	Sub-Categories (merged)
Social Sciences and Humanities	26,157	Multidisciplinary Sciences; Psychology (General, Applied, Biological, Clinical, Developmental, Educational, Experimental, Mathematical, Multidisciplinary, Psychoanalysis, Social); Humanities (Multidisciplinary); Anthropology; History & Philosophy of Science; Philosophy; History; Education (General & Educational Research, Scientific Disciplines, Special); Law; Sociology; International Relations; Social Issues; Social Sciences (Biomedical, Interdisciplinary, Mathematical Methods)
Management	22,248	-
Economics	17,094	-
Business	15,796	Business (general, finance)
Engineering	7,830	Engineering (Aerospace, Biomedical, Chemical, Civil, Electrical & Electronic, Environmental, Geological, Industrial, Manufacturing, Marine, Mechanical, Multidisciplinary, Ocean, Petroleum); Operations Research and Management Science
Information and computer science	6,578	Computer Science (Artificial Intelligence, Cybernetics, Hardware & Architecture, Information Systems, Interdisciplinary Applications, Software Engineering, Theory & Methods); Information Science and Library Science
Planning & Development	6,081	-
Geography & environment	5,989	Geography (general, physical); Environmental Studies; Urban Studies
Health	4,637	Environmental Sciences; Healthcare Sciences & Services; Communication; Public, Environmental & Occupational Health; Medicine (General & Internal, Legal, Research & Experimental); Nursing
Political Science	2,200	-
Public Administration	1,348	-
History of Social Sciences	776	-
Industrial Relations & Labour	747	-

Figure B1. Relationships between subject-areas (cut off = 0.9)



Note: This network graph illustrates the relationship between the (main) subject categories, which involves users of knowledge produced by the (core) innovation literature. These relationships refer to the extent to which the sampled publications from two different subject categories cited the same literature (each of the 147 most important works on innovation). Several subject-areas were composed based on these relationships (see Table B). The strength of the relationships is indicated by line thickness, where no lines mean rather weak relationships (less than 90% relationship strength). The subject categories are represented by circles of different sizes and colours, based on their total amount of citations to the core innovation literature (large blue, medium orange and small red circles).

Figure B2. Relative citation intensity across subject-areas (6-year average, 2003 – 2008)



Source: Own calculations based on statistics from ISI journal citation reports.
Note: Citation intensity refers to the number of references per journal article in the subject-area.

Appendix C

Table C. Two-Step Cluster Analysis (best solutions based on BIC and log-likelihood distance)

Number of clusters	*4*				*3*			*2*	
BIC	-4264.90				-4325.30			-4366.36	
Ratio of Distance Measures	1.24				1.14			2.77	
Cluster (Number of members)	1/4 (28)	2/4 (56)	3/4* (29)	4/4* (34)	1/3* (28)	2/3* (56)	3/3 (63)	1/2 (84)	2/2 (63)
Disciplinary orientation									
Social Sciences & Humanities	0.16	0.19	**0.34**	0.09	0.16	0.19	**0.20**	0.17	**0.20**
Management	0.34	0.18	0.34	**0.50**	0.34	0.18	**0.44**	0.23	**0.44**
Economics	0.22	**0.43**	0.05	0.07	0.22	**0.43**	0.06	**0.36**	0.06
Business	0.20	0.23	0.36	**0.49**	0.20	0.23	**0.42**	0.23	**0.42**
Engineering	0.24	0.14	0.26	**0.48**	0.24	0.14	**0.37**	0.18	**0.37**
Information & Computer Science	0.15	0.09	**0.34**	0.22	0.15	0.09	**0.27**	0.11	**0.27**
Planning & Development	**0.67**	0.41	0.10	0.26	**0.67**	0.41	0.19	**0.49**	0.19
Geography & Environment	**0.25**	0.23	0.05	0.04	**0.25**	0.23	0.04	**0.24**	0.04
Health	0.05	0.04	**0.14**	0.08	0.05	0.04	**0.11**	0.04	**0.11**
Political Science	0.08	**0.12**	0.04	0.02	0.08	**0.12**	0.03	**0.10**	0.03
Generation and selection processes									
RP	**0.54**	0.28	0.04	0.25	**0.54**	0.28	0.16	**0.36**	0.16
SMJ	0.08	0.15	0.17	**0.34**	0.08	0.15	**0.26**	0.13	**0.26**
Insider	**0.36**	0.15	0.06	0.24	**0.36**	0.15	0.16	**0.22**	0.16
Excellence	**0.65**	0.32	0.13	0.38	**0.65**	0.32	0.26	**0.43**	0.26
SPRU	**0.57**	0.01	0.01	0.15	**0.57**	0.01	0.08	**0.20**	0.08
Thematic orientation									
Innovation	0.75	0.07	0.21	**0.76**	**0.75**	0.07	0.51	0.30	**0.51**
Technology	0.36	**0.39**	0.00	0.29	0.36	**0.39**	0.14	**0.39**	0.14
Economy	0.18	**0.34**	0.07	0.00	0.18	**0.34**	0.03	**0.29**	0.03
R&D	0.04	**0.20**	0.10	0.00	0.04	**0.20**	0.05	**0.14**	0.05
Knowledge	0.00	0.02	0.14	**0.26**	0.00	0.02	**0.21**	0.01	**0.21**
Micro	0.00	0.04	**0.52**	0.38	0.00	0.04	**0.44**	0.02	**0.44**
Management	0.00	0.02	**0.14**	0.12	0.00	0.02	**0.13**	0.01	**0.13**
Industry	**0.18**	**0.18**	0.00	0.09	**0.18**	**0.18**	0.05	**0.18**	0.05
Change	0.21	**0.23**	0.00	0.06	0.21	**0.23**	0.03	**0.23**	0.03
Macro	**0.21**	0.18	0.00	0.00	**0.21**	0.18	0.00	**0.19**	0.00

* denotes the two groups of innovation literature which are integrated in the subsequent stage

Note: For Thematic orientation, numbers represent shares of literature within each group which have the respective keyword in the title. Numbers represent variable means for the other two dimensions (Disciplinary orientation, Generation and selection processes). Numbers in bold indicate the highest means/shares.

Chapter 3
INNOVATION STRATEGIES AS A SOURCE OF PERSISTENT INNOVATION[1]

Abstract

An important topic in the recent literature on firms' innovation is the question of whether, and to what extent, firms which innovate once have a higher probability of innovating again in subsequent periods. This phenomenon is called the 'persistence of innovation'. Although the literature has established that innovation persistence is indeed important from an empirical point of view, relatively little attention has been paid to identifying the reasons why this is the case. This study proposes that the differences in innovation strategies across firms are an important driving force behind innovation persistence, and analyses this issue using a panel database constructed from R&D and Community Innovation Surveys in Norway. Empirical measures of various innovation strategies are identified by means of a factor analysis. A cluster analysis is used in addition to a dynamic random effects probit model to extend the methodology adopted by prior studies, for the purpose to not only examine innovation persistence, but also determine how this persistence is influenced by innovation strategies. The results support the idea that the differences in innovation strategies across firms are an important determinant of the firms' probability to repeatedly innovate. The study also distinguishes the effects of strategy differences on the persistence of product and process innovation in all firms, and within high-tech versus low-tech firms.

[1] Co-authored with Tommy Clausen, Mikko Pohjola, and Bart Verspagen.

1. Introduction

An important issue in the recent literature on firm-level innovation is whether, and to what extent, firms which innovate once have a higher probability of innovating again in subsequent periods. This phenomenon, which may be referred to as 'innovation persistence', has been addressed by a number of empirical studies using Community Innovation Survey (CIS) data (for example, Duguet and Monjon, 2004; Peters, 2009; Raymond et al., 2006), as well as other types of data (mainly patents, for example, Geroski et al. 1997; Malerba and Orsenigo 1999; Cefis 2003). Innovation persistence is usually specified in the econometric sense by a model in which the probability of a firm innovating is explained by a variable which measures whether or not the firm had innovated in a previous period (i.e. the lagged dependent variable), as well as a number of control variables. If the lagged innovation variable has a positive and significant sign, this is interpreted as persistence within the context of innovation. This finding is supplied by many studies of innovation persistence.

The present study somewhat deviates from the existing literature on innovation persistence in the sense that it is not primarily interested in the traditional question of whether or not, and to what extent, innovation is persistent. Instead, this study strives to answer why some firms (do not) persistently innovate. The variables which influence this, such as whether or not a firm has an R&D department, or whether or not it maintains cooperative relationships for innovation, are affected by the long-run strategic choices made by the firm (see, for example, Nelson and Winter 1982; Teece et al. 1997). In this study, these factors are referred to as the 'innovation strategy' of the firm, and this notion will be operationalised below. To the authors' knowledge, none of the prior studies in the "innovation persistence" tradition has explicitly analysed the strategic factors behind innovation persistence at the firm level. Therefore, the question pursued by the present study is to what extent do differences in innovation strategies across firms explain why some firms persistently innovate? This research question is in line with a recent review of the capability literature, which argues that prior studies have not, in general, analysed the relationship between the capabilities and resources of firms, nor have they evaluated how these influence "the persistence of above average performance" (Hoopes and Madsen, 2008:394).

Following evolutionary theory and strategic management research, it is a central tenet of the approach of this study that there are important differences between firms in terms of how they innovate, and that this leads to different innovation probabilities at the firm level. As discussed below, the differences between firms, i.e. innovation strategies, are measured by using the European-wide harmonised Community Innovation Survey (CIS) questions on innovation activities (for example, R&D, marketing or design), information sources (for example, internal or external to the firm) and the major goals a firm seeks to achieve by innovating (for example, gaining market share or saving labour costs). This study proposes that these variables capture the major elements of a firm's tendency to persistently innovate. Following on logically from the desire to measure firm characteristics in a rather precise way, two major types of innovation are distinguished in the study, i.e. product and process innovation. Although some prior studies have examined the persistence of product and process innovation, none of them has examined the driving forces behind innovation persistence within these two categories. This is the main contribution of the study to the literature.

The study's focus on the strategic driving forces behind persistent innovation is in line with the recent literature on innovation studies, which have begun to conduct a longitudinal analysis of firms in order to identify persistent heterogeneity and its causes (Dosi et al., 2008). Where others in the field have focused on profit and productivity persistence (see Bottazzi et al., 2008, for an example), the focus of this study is persistent innovation (and its driving forces), which is considered to be a key factor of profit and productivity persistence. As such, the study fits comfortably within the recent "persistent heterogeneity" topic in innovation studies. The study uses a panel dataset, constructed on the basis of R&D and CIS surveys from Norway,[2] and adopts a dynamic random effects probit model (Wooldridge, 2005). This model is similar to that used in most recent studies which address innovation persistence based on CIS data (for example, Peters, 2009; Raymond et al., 2006). However, the present study contributes to the literature by extending the Wooldridge model in a simple way, which enables an examination of whether, and to what extent, different types of innovation strategies relate to innovation persistence. The econometric specification used, which includes innovation strategies, nests the approach used in previous studies as a special case. In other words, this method provides a natural way to incorporate the idea in evolutionary theory that firms are different and innovative in diverse ways, and that the ways in which firms innovate may influence their ability to persistently innovate.

[2] Innovation and R&D survey data is widely used in innovation studies. See Laursen and Salter (2006), Reichstein and Salter (2006), Vega-Juardo et al. (2009), for recent examples.

Following this introduction, Section 2 firstly provides a short overview of the previous empirical literature on innovation persistence, and subsequently looks at the particular mechanisms for the persistence of innovation at the firm level suggested by the literature. The section also discusses how this leads to the theoretical perspective of this study, which will guide its empirical model. Section 3 presents the data and analytical method, and the empirical approach to measure a firm's innovation strategies is explained in Section 4, while Section 5 presents the econometric results. The last section provides a summary, and ends by proposing some recommendations for further research.

2. Theoretical Background and Prior Literature

2.1. Prior empirical research on innovation persistence

After the first studies appeared in the 1990s, the issue of whether or not innovation is persistent at the firm level has been addressed by many quantitative papers, especially recently. Although the basic empirical setting and econometric models used differ across studies, innovation persistence has always been examined by including lagged innovation as a predictor of current and/or future innovation. The literature on innovation persistence uses two different types of indicators of innovation. On the one hand, some prior studies apply patent data and R&D data, and on the other hand, more recent studies focus on questionnaire-based measures of innovation (for example, the CIS and the like). Somewhat simplified, survey questions about product and process innovation are considered to be output-based measures of innovation, while R&D is an input, and patents are a measure of invention. Early studies on innovation persistence mainly used patent data, and these studies found low, or no clear-cut, persistence of innovation (Geroski et al., 1997; Malerba and Orsenigo, 1999; Cefis and Orsenigo, 2001; Cefis, 2003). More recently, panel datasets based on the CIS have been made available to researchers, and recent studies tend to be more positive about whether or not innovation is persistent when using this data.

Using a dynamic count panel data model to link past and current innovations (in terms of the number of patents and/or R&D expenditure), Crepon and Duguet (1997) reported a high persistence of innovation among R&D intensive firms in France. Duguet and Monjon (2004) and Rogers (2004) both estimated a cross-sectional probit model and found strong innovation persistence in French and Australian firms, respectively. Focusing on R&D activities, Castillejo et al. (2004) examined the persistence of innovation in Spanish manufacturing firms by using a dynamic probit model and panel data. They found that the influence of past R&D experience on the current decision to undertake R&D was positive and significant. In a recent study of firms in the German service and manufacturing industries, Peters (2009) used a dynamic random effects binary choice model and panel data to examine the persistence hypothesis. Her findings showed a high persistence of innovation activities in both manufacturing and services. In the service sector, however, the effect of innovation in the previous period on innovation in the current period was smaller than it was in manufacturing. In another recent analysis of Dutch manufacturing firms, Raymond et al. (2006) examined innovation persistence separately for high-tech and low-tech sectors. They found that firms in the high-tech sector innovated persistently, while this was not the case for low-tech firms.

When patents, R&D expenditure or innovation expenditure are used as the main data source, it is hard (or impossible) to differentiate between process and product innovation. However, to do so seems important, because these two types of innovation are of quite a distinct nature. Process innovation often requires less technological advancement and strategic decision-making (Rosenberg, 1982; Tushman and Rosenkopf, 1992). It is also often related to learning-by-doing, and linked to innovation strategies which are believed to be less developed compared to strategies for product innovation (Cabral and Leiblein, 2001; Pisano, 1997). This is why process innovation and product innovation may be expected to show different levels of persistence. In literature which addresses the evolution of industries, process innovation is usually regarded as being persistent in relatively mature industries where the focus is more on creating new, more efficient production processes than on introducing new products (Klepper, 1997; Utterback, 1994). In other words, persistence is likely to vary between the two types of innovation according to different industries.

To the authors' knowledge, only one previous study by Flaig and Stadler (1994) has examined whether, and to what extent, process and product innovation are persistent at the firm level. They used a dynamic random effects probit model and found that firms were persistent in both product and process innovation, but that there was no dynamic cross effects between these types of innovation. In other words, innovation of one type in the previous period did not explain the current innovation of the other type.

Some studies have found low persistence in the innovation activity of firms. Examples include Geroski et al. (1997) who used data on patents as well as "major" innovations for the

UK (and a duration dependence model), and Malerba and Orsenigo (1999), Cefis and Orsenigo (2001) and Cefis (2003) who analysed EPO (European Patent Office) patent application data for manufacturing firms in France, Germany, Italy, Japan, the UK and the US. However, patents are not the same as innovations (Smith, 2004).[3] The discussion of the literature in the present study suggests that persistency studies which have used patents as a proxy for innovation tend to identify a low degree of innovation persistence, while studies using either R&D or "output"-based measures of innovation tend to find a higher degree of innovation persistence within firms. Altogether, it is clear that innovation persistence is not a clear-cut phenomenon, and that it requires a more in-depth research setting which can facilitate an analysis of the driving forces of persistent innovation.

2.2. Why is innovation persistent at the firm level?

Previous research has identified three broad theories to explain why some firms are persistent innovators (and why others do not persistently innovate). The first line of reasoning is based on the idea that "success breeds success" (Nelson and Winter, 1982; Flaig and Stadler, 1994). This idea stresses that prior commercial success in the form of a successful innovation creates profits which can be invested in current and future innovation activities. Because of financial constraints related to the risky nature of R&D and innovation (see Hall, 2002a, b for a survey of the literature which addresses this issue), retained profits and past commercial success in previous innovative activities are considered to be particularly important for the financing of (new) innovation projects.

A second line of reasoning argues that some firms become persistent innovators due to dynamic economies of scale and "learning-by-doing" (Arrow, 1962; Nelson and Winter, 1982; Dosi 1988). This may be the result of the very nature of knowledge itself, which is cumulative and used as an input to generate new knowledge. It is often argued (see, for

[3] To use patent data to analyse innovation persistence may be problematic, since patents are heavily criticised as being a wrong measure for innovation. With only some exceptions, such as in the biotechnology industry in which many firms try to obtain a patent as the way to commercialise what they have invented (i.e. to innovate), it would be more appropriate to treat a patent as an invention since to patent does not necessarily mean to innovate. This is because, for the sake of accuracy, according to Schumpeter (1911, 1942; see also Fagerberg, 2004), innovation should refer to the action or process of putting a new idea or model into practice, i.e. the introduction of an invention in the form of a new product or process into the economic or social system. Moreover, for a firm to be registered to have patented in a patent database, it needs to win a patent/invention race and be the first to apply for a patent. The persistence (not) found in patent data may, therefore, refer only to the success (or failure) in winning the patent race on a persistent basis. This suggests that the analysis using patent data may end up representing a story about persistence of invention or inventive leadership, not that of innovation.

example, Malerba and Orsenigo, 1996) that this is particularly important in some sectors where the knowledge base is very cumulative, implying that experience in R&D makes firms more efficient in innovating. In addition, learning-by-doing may take the form of 'procedural knowledge', because a firm may simply learn from dealing with the various tasks or problems it faces. This method of learning also refers to the management of relationships with external partners, such as universities, which is closely related to the notion of learning by interacting (Lundvall, 1988; Jensen et al., 2007). Assuming that the depreciation rate of innovative abilities is small, Raymond et al (2006) explain that knowledge which has been used to produce past innovations can be used again in the making of current, or even future, innovations. This line of reasoning emphasises a firm's persistent innovation behaviour.

Based more or less implicitly on a linear view of innovation, the third and final line of reasoning argues that innovation persistence at the firm level can be explained by the largely sunk nature of R&D costs (Sutton, 1991; Cohen and Klepper, 1996). From this perspective, R&D is not an activity which can be easily discontinued one year, and started again in the next year, mainly because knowledge is embodied in the human capital of researchers. Thus, whether or not to invest in an R&D laboratory is a long-term decision, and once that decision has been taken, the firm is expected to have a constant flow of innovation, rather than a one-off. Thus, innovation becomes persistent.

Nevertheless, R&D is not the only innovation input/source (Arundel et al., 2008; Leiponen and Helfat, 2010). Other inputs include external knowledge (for example, in the form of cooperation, alliances, or licensing; see Bodas Freitas et al., 2008; Laursen and Salter, 2006), and internal activities like design, marketing, training, etc. Intuitively, not all of these innovation sources are associated with the same strong level of persistence as R&D. For example, buying a license could be a one-off activity, leading to a single innovation, and the training of employees could relate to a single innovation project. When innovation or knowledge can be bought in the marketplace (Arora et al, 2001), persistence may also be low. On the other hand, strategic alliances in which knowledge is jointly developed between firms (Duysters and Hagedoorn, 1996; Vonortas, 1997), user-producer interactions (Von Hippel, 1988; Jensen et al., 2007), or cooperation with universities and public research institutes (Mowery and Sampat, 2004; Nelson, 1993) may have important sunk costs and may, therefore, be more durable.

From this perspective, the degree of innovation persistence observed in a particular firm depends on the specific mix of innovation inputs or sources the firm uses. This suggests that it is important to include variables which measure these inputs in a regression framework aimed at identifying or explaining innovation persistence. This proposition is the key element of the contribution of the present study. However, whether or not such an approach is feasible depends, to a large extent, on the degree to which these innovation inputs themselves can be considered as being exogenous at the level of the regressions. In other words, whether or not there is merit in attempting to explain innovation persistence depends on what is known about the background of the differences between firms which may relate to a varying degree of innovation persistence.

This study contends that, given that the data used has, at most, three observations (on innovation) per firm spanning a decade in total (see below), the differences between firms in terms of the choice of innovation inputs can indeed be considered as being largely exogenous. These differences will be measured at the outset of the 10-year period observed, and then it will be assumed that these observed differences explain innovation and persistence over the next observations. The (assumed) long-run nature of these differences between firms is the main reason for referring to them as 'strategic' differences, i.e. innovation strategies are spoken of as factors which may account for differences in innovation and innovation persistence across firms. The justification of this assumption, which may seem heroic to some, comes from two related fields of literature which have influenced the recent discourse on innovation, namely, evolutionary economics and strategic management. Evolutionary economics deals with the processes of variation, selection and retention (Aldrich, 1999; Nelson and Winter, 1982). It argues that firms possess a set of semi-stable routines in which they store factors which affect innovation, as well as other strategic factors of the firm's behaviour. Although these routines are subject to change, this does not often occur, and generally, any such changes are not radical (Nelson and Winter, 1982; Cyert and March, 1963; Levitt and March, 1988). Because the routines are not based on a decision-making model with rational expectations or full information, and because firms differ in respect of their pre-determined knowledge and resources, they imply a relatively large degree of firm heterogeneity which evolves only slowly under the pressure of market selection. In the words of Nelson and Winter (1982:14), "... routines play the role that genes play in biological evolutionary theory. They are a persistent feature of the organism and determine its possible behaviour".

Strategic management literature identifies the notion of competencies or capabilities as explaining innovation and innovation persistence at the firm level (for example, see Penrose, 1959; Grant, 1996; Winter, 2003). Existing literature on competencies addresses the resources or capabilities firms need in order to successfully create and sustain a competitive advantage. Competencies related to innovation and change within a firm are sometimes referred to as dynamic capabilities (Teece et al., 1997). The theory states that firms need to create or acquire these dynamic capabilities in order to be able to successfully innovate in a changing competitive environment. Dynamic capabilities are "higher level" competencies which enable the firm to continually renew its resource and knowledge base in order to keep up with the demands of the market, and persistently innovate (Winter, 2003). What this discussion simply suggests is that firms have dynamic capabilities, and dynamic capabilities lead them to pursue different innovation strategies.

The stable nature of strategic firm behaviour is also stressed in strategic management literature (see Hoopes and Madsen, 2008, for a review). In this respect, the notion of inertia plays an important role. Similar to the idea of semi-stable routines, the concept of inertia is that a firm's strategy is stable, hard-to-change and persistent at the firm level (for example, see Helfat, 1994; Stuart and Podolny, 1996). Winter (2003) argues that firms may innovate even without a strategic focus, or develop innovations in a non-routine way by *ad hoc* problem solving. However, theory predicts that persistent innovation is not likely without a clear strategy backed up by the relevant capabilities, and this is reinforced, for example, by the interaction between the firm's knowledge base and its absorptive capacity. Firms with more (relevant) knowledge and a better developed absorptive capacity are in a better position to innovate (Cohen and Levinthal, 1989, 1990), but innovation itself reinforces absorptive capacity. This latter aspect is sometimes referred to in the literature as double loop learning (Argyris and Schon, 1978). This mechanism can be extended to the Open Innovation model (Chesbrough et al., 2006), which has recently been influential in strategic management literature. Firms which are more "open" in the innovation process reap higher sales and profits from new innovations (Laursen and Salter, 2006)[4] which, in turn, may enable future innovation (i.e. the proposition of success breeds success, as discussed above).

[4] Laursen and Salter (2006) suggest that searching more widely and deeply for ideas or knowledge from external sources increases the benefits of open innovation. However, over-search (in terms of breadth and depth) may result in decreasing returns.

In conclusion, it is argued that prior studies of innovation persistence have made a valuable contribution to innovation literature by demonstrating that firms which innovate once tend to innovate again in the future. However, prior empirical research can be perceived as only having had a loose coupling to theory, and no prior study in this literature has taken relevant theories into account when analysing why innovation is persistent at the firm level. In comparison, prior studies have focused on the explanatory power of the lagged innovation variable for current innovation, but this, in itself, cannot explain whether or not the persistent condition observed is caused by sunk costs, "success breeds success", learning by doing, or a combination of these. Therefore, this begs the question, "Why do some firms persistently innovate?"

The approach taken by the present study is to attempt to answer this question by relying on measuring a set of stable firm innovation characteristics, referred to as innovation strategies, and to use these to explain innovation in an econometric model. Because these innovation strategies are measured at the outset of the observed period (see below), a significant and positive impact on subsequent innovation occurrence would point to an element of innovation persistence which can be interpreted in the light of the theoretical perspectives discussed here. In other words, this study puts forth the argument that strategic differences across firms are persistent, and this helps to explain why some firms innovate persistently, while others do not.

3. Data and Methodology

The research in this study builds on a panel database created by Statistics Norway. The main objective of creating this database has been to track firms over time on key variables such as innovation, R&D, employment and sales. The database contains information about all enterprises which have participated in at least one of the R&D surveys conducted by Statistics Norway since 1993. These surveys are a census for firms with 50 or more employees, but a sample for smaller firms. As a consequence, large firms have a much higher probability of being included in several surveys rather than small firms. The R&D survey is conducted every second year, and thus, the panel consists of waves of two years.

This study utilises part of the R&D panel. The first year of the dataset used is 1997, in which this R&D data was combined with data from the Community Innovation Survey for year 1997 (so called CIS2). The CIS2 questions on innovation applied in this study refer to the past three years, for example, the CIS2 survey asks whether or not the firm innovated in the period between 1995 and 1997. Because the surveys are conducted every two years, the innovation questions have an overlap of one year, and this may introduce an element of spurious persistence which is a potential significant problem (potentially much larger than the 10% which Raymond et al. 2006 suggest). Therefore, the present study finds it necessary to create a sample without any overlap in the measurement period. In this study, the innovation variables used refer to the periods 1995-1997, 1999-2001, and 2002-2004. A survey covering the period between1998 and 2000 does not exist, which is why the study is forced to leave a one-year gap between the first and second wave in the dataset. Because a lagged dependent variable is adopted as one of the regressors, the regressions use two observations per firm at most (this is the case for firms which are present in all 3 waves). Moreover, since the initial observation (data from the CIS 2) is used to measure the innovation strategies, the sample used in the regressions is limited to those firms which were present in the initial wave (the CIS 2). And because the questions about innovation in services are incompatible between the waves, the service sector is excluded from the dataset, i.e. the sample is limited to industry (mining, manufacturing, public utilities and construction).

Two dependent variables, namely, product innovation and process innovation, are employed one at a time. These variables are directly observed in the survey, and are binary. The value 1 for the product or process innovation variable indicates that the firm had one or more respective innovations (either product or process) during the 3-year period. Product and process innovations have been defined according to the so-called Oslo manual (see OECD/Eurostat, 2005), and refer to technological innovations which are new to the firm, but need not necessarily be new to the industry, or the world.

One of the control variables used in this study is firm size (from which larger firms are expected to have a higher probability to innovate, i.e. Schumpeter Mark II, 1942), and this is measured by the number of employees a firm has (as reported in the survey). The other control variables are industry dummy variables, time dummy variables, and innovation strategy dummy variables. Table 1 documents the summary statistics of the main variables used in the regressions, broken down by waves of the survey (wave 2 refers to the first observation used in the regressions, since wave 1, which is the CIS 2, is used only for lagged innovation variables). Both employment and ln(employment) are documented, but only the latter is used in the regressions. With an average number of 183 employees, the firms in this sample seem fairly large by Norwegian standards. This is a result of the fact that larger firms have a higher probability of being included in the sample, because of the aforementioned sampling method used by Statistics Norway. Also because of this sampling method, the average firm size in wave 3 is larger than in wave 2, i.e. those (larger) firms which are present in wave 3 are also present in the two previous waves (as opposed to the firms present in wave 2, which need not be present in wave 3). In addition, the statistics in Table 1 demonstrate that the employment variable has a high standard error, which is the result of the skewed nature of this variable. In fact, there are a few very large firms in the sample, the largest of which has more than 11,000 employees.

Table 1 also reports that product innovation is more frequent (about 41% of all observations) than process innovation (about 34%). Moreover, both forms of innovation are more frequent in wave 2 than in wave 3, although this difference is much larger for process innovation (a drop from 38% to 26%) than for product innovation (42% to 39%).

Table 1. Descriptive statistics

	total			*wave=2*			*wave=3*		
	valid n	Average	St. error	valid n	Average	St. error	valid n	Average	St. error
Employment	1510	183.4	490.0	905	170.6	435.4	605	202.6	561.6
ln(Employment)	1509	4.423	1.137	904	4.368	1.133	605	4.505	1.140
Product innovation	1476	0.409	0.492	905	0.420	0.494	571	0.391	0.488
Process innovation	1510	0.335	0.472	905	0.383	0.486	605	0.263	0.441

Table 2 illustrates the transition probabilities for the innovation status of firms for both types of innovation. The sums of the values on the diagonal are an indication of persistence, as they indicate the fraction of firms which stay in the same class, being persistent innovators or persistent non-innovators (Cefis, 2003). These values are all high (above 0.5, with one exception), which suggests that persistence is indeed prevalent in the sample (but of course, this needs to be further tested in a regression model which includes control variables). However, process innovators seem to be less persistent. In both periods, firms which were initially process innovators have a relatively low probability of staying that way (compared to product innovators). In the second period (wave 2 – 3), process innovators have an even larger probability of being non-process innovators in the next wave than remaining as process innovators (0.6 versus 0.4).

The difference between the two cells in the second column of each matrix indicates the 'bonus' enjoyed by an initial innovator over an initial non-innovator in terms of innovation probability. Although these observed differences do not control for variables such as firm size and other (observed or non-observed) heterogeneity, they can serve as a rough benchmark of what to expect in the regressions. The observed differences range from 22% (process innovation in the first period) to 42% (product innovation in the second period).

Table 2. Transition probabilities

Period 1 (wave 1 – 2)				**Period 2 (wave 2 – 3)**			
Product innovation		*wave =2*				*wave =3*	
		No	Yes			No	Yes
wave =1	No	0.73	0.27	*wave =2*	No	0.80	0.20
	Yes	0.34	0.66		Yes	0.38	0.62
Process innovation		*wave =2*				*wave =3*	
		No	Yes			No	Yes
wave =1	No	0.71	0.29	*wave =2*	No	0.83	0.17
	Yes	0.49	0.51		Yes	0.60	0.40

Note: The transition probabilities in each matrix are calculated for the firms that are present in the two successive waves considered (wave 1 – 2, wave 2 – 3).

Since the dependent variables employed are binary, a probit regression model is selected. This study follows the standard modelling procedure for analysing (innovation) persistence, i.e. the lagged dependent variable is included as an explanatory variable in the model in order to test the persistence hypothesis. The specific estimation model used is a dynamic random effects probit model. Obviously, in such a model, the probability of innovation is dependent on the past innovative history of the firm, and this can be traced back to the initial observation in the sample (wave 1). This initial observation proxies for otherwise unobserved firm's characteristics, and hence, as suggested by Wooldridge (2005), this initial observation is included, in addition to the lagged dependent variable. It is important to account for heterogeneity in this way, since otherwise the coefficient obtained for the lagged dependent variable may be biased (overestimated) (Raymond et al., 2006; Peters, 2009). Taking into account unobserved firm heterogeneity (by means of random effects), as well as the initial value of the dependent variable, provides a dynamic framework, in which a significant lagged dependent variable indicates true, not spurious, state dependence (Heckman, 1982).

In this study, a simple extension to the Wooldridge method (Wooldridge, 2005) is also devised to enable an analysis of the influence of innovation strategies on persistent innovation. Principally, the Wooldridge method incorporates an initial condition dummy variable which is coded 0 if firms did not innovate at t1 and 1 if firms innovated at t1, and this initial condition variable is fixed throughout the panel data analysis. The extension to this method is simply that subgroups of firms which innovated at t1 will be distinguished by using factor and cluster analyses. The CIS2 data used, which represents the time period t1 in the panel, contains various details about innovation in firms, and latent firms' strategies will be identified based on this information, by utilising a factor analysis. A cluster analysis will then categorise innovative firms at t1, based on how they score on the latent factors obtained from the factor analysis. This is important, because the results of the cluster analysis will help to identify subgroups of innovative firms which differ in their approach to innovation at t1. The identified clusters will be represented in the analysis by cluster dummies, where value 1 signals that an innovative firm at t1 belongs to the respective cluster (and not to the others). As the cluster analysis is undertaken using data of only innovative firms at t1, the cluster dummy variables can simply be combined and transformed back into the original dummy variable measuring the "initial innovation condition". Thus, factor and cluster analyses are two essential steps to be taken in order to examine whether, and to what extent, innovation strategies influence persistent innovation at the firm level over time.

4. Measuring innovation strategies by factor and cluster analyses

This section conceptualises innovation strategies, and categorises firms based on their strategies. The review in Section 2 suggests that firms use various knowledge sources and engage in a range of learning activities (for example, through different routines) in the innovation process. Thus, a first step is to identify latent variables or principle components which capture a variety of sources, objectives and activities related to innovation in firms. For this purpose, a factor analysis is undertaken on the relevant groups of variables extracted from the CIS2 questionnaire. The structure of the questionnaire is such that firms which do not report any product or process innovation are not allowed to answer the questions concerned, and these firms are excluded from the factor analysis. Therefore, the results reported in this section are based only on firms which have carried out some innovation activities.

4.1. Results of factor analysis

Table 3 reports the results of the factor analysis on the set of CIS2 questions which indicate the extent to which the sampled firms were active in different types of innovation activities. The particular factor pattern identified in the table suggests two broad innovation approaches, similar to the "make versus buy" option in technology sourcing. The "make" strategy includes a combination of internal and external R&D, and the market introduction of innovation. The "buy" strategy incorporates reliance on machinery and equipment procurement, external technology, and training related to innovation. This result is in line with that of Veugelers and Cassiman (1999), which demonstrates that firms differ in how they use "make" and "buy" strategies.

Table 3. Innovation activities

	Make	*Buy*
-Research and experimental development within the enterprise (intramural R&D)	**0.88**	-0.05
-Acquisition of R&D services (extramural R&D)	**0.82**	0.00
-Acquisition of machinery and equipment linked to product and process innovations	-0.18	**0.72**
-Acquisition of other external technology linked to product and process innovations	0.09	**0.65**
-Market introduction of technological innovations	**0.52**	0.32
-Training directly linked to technological innovations	0.12	**0.71**

Note: 57 % of total variance explained by the two factors; principal components factoring with oblique oblimin rotation, chi^2 (15) = 828.71, Prob. >chi^2 = 0.00, Numbers in bold indicate moderate to high factor loadings.

Table 4 illustrates the results of a second factor analysis, which aimed to identify latent factors in relation to the objectives of firms for innovation. It is assumed that firms differ in terms of innovation goal setting, and that this difference will enable the estimate to detect the factors which account for firm heterogeneity in the innovation process. According to the results, the common goals can be broadly categorised into a "production" dimension (reducing inputs and costs, while improving quality and satisfying standard requirements), and a "market" dimension (competing with better and more products).

Table 4. Innovation Objectives

	Production	*Market*
-Replace products being phased out	0.20	**0.53**
-Improve product quality	**0.46**	0.32
-Extend product range	-0.06	**0.82**
-Open up new markets or increase market share	-0.01	**0.81**
-Fulfil regulations, standards	**0.59**	0.05
-Reduce labour costs	**0.72**	-0.11
-Reduce materials consumption	**0.75**	0.13
-Reduce energy consumption	**0.83**	0.01
-Reduce environmental damage	**0.77**	-0.11

Note: 53 % of total variance explained by the two factors; principal components factoring with oblique oblimin rotation, chi^2 (15) = 828.71, Prob. >chi^2 = 0.00, Numbers in bold indicate moderate to high factor loadings.

Following the discussion in Section 2, different types of knowledge sources used in a firm's innovation process are also of interest. Therefore, a factor analysis was undertaken on the set of CIS2 variables which provide such information. The results indicated in Table 5 suggest the presence of three main characteristics or functions of sources of information used by the firms for innovation. The first is labelled "Science", and captures information from universities, research institutes, patents and, to a lesser extent, from computer networks and consultants. The second is labelled "Industry", and includes many sources within industry (including the firm's internal sources, customers, and competitors). The third is labelled "Opportunistic", and refers to the fact that this factor includes a number of sources which require relatively little effort on behalf of the firm which adopts them (suppliers of equipments, journals, professional conferences, fairs and exhibitions).

Table 5. Sources of information for innovation

	Science	*Industry*	*Opportunistic*
-Sources within the enterprise	0.15	**0.58**	-0.26
-Competitors	-0.05	**0.67**	0.23
-Clients or customers	-0.02	**0.81**	-0.06
-Consultancy enterprises	**0.41**	0.12	0.24
-Suppliers	-0.02	-0.15	**0.81**
-Universities	**0.86**	-0.04	-0.02
-Non-profit research institutes	**0.86**	-0.12	0.01
-Patent disclosures	**0.64**	0.24	-0.08
-Professional conferences, journals	0.34	0.07	**0.55**
-Computer information networks	**0.53**	0.23	0.21
-Fairs, exhibitions	-0.00	0.38	**0.60**

Note: 55 % of total variance explained by the three factors; principal components factoring with oblique oblimin rotation, chi^2 (15) = 828.71, Prob. >chi^2 = 0.00, Numbers in bold indicate moderate to high factor loadings.

4.2. Identifying innovation strategies by means of hierarchical cluster analysis

In order to identify the innovation strategies of the sampled firms, the results obtained from the factor analysis were used in a subsequent cluster analysis. Clustering was undertaken on the factor scores for the seven principal components documented in the previous three tables. The clustering procedure used was a hierarchical clustering, in which each firm was initially located in a separate cluster (so that the initial number of clusters was simply the total number of firms), and then the two most similar clusters were joined together sequentially at each step. Ward's method was adopted as the linkage function. Empirical validation was based on the agglomeration schedule of the hierarchical cluster process. The Calinski/Harabasz pseudo-F stopping rule was used, which indicated the solution to be between 2 to 5 clusters. Although the general custom is to report only a single cluster solution, in order to decrease the subjectivity of the analysis, and because there is no theoretical reason for expecting a single solution, a range of cluster solutions was opted for use. The four cluster solutions are reported in descending order, from five to two (as mentioned above, two of the most similar clusters were combined at each step). Table 6 documents the average factor scores in each of the clusters in different cluster solutions. Since the factor scores are standardised variables with a mean of zero and a standard deviation of one, a positive (negative) number in the table indicates an above (below) average result.

Table 6. Hierarchical Cluster Analysis

	Make	Buy	Production	Market	Science	Industry	Opportunistic	N (%)
5-Clusters								
Strategy 1/5 -Supplier-based	-0.71	0.34	0.11	0.04	-0.47	0.01	0.54	271 (28.3)
Strategy 2/5 -Ad Hoc	-0.84	-0.36	-0.68	-1.70	-0.76	-1.67	-0.34	85 (8.9)
Strategy 3/5 -Market-driven	0.09	-0.47	-0.55	0.35	-0.55	0.17	-0.91	240 (25.1)
Strategy 4/5* -R&D intensive	1.17	1.15	0.52	0.67	0.83	0.71	0.46	129 (23.5)
Strategy 5/5* -Science-based	0.39	-0.43	0.41	-0.11	0.95	0.09	0.20	231 (24.2)
4-Clusters (5-Clusters with 1 restriction)								
Strategy 1/4* -Supplier-based	-0.71	0.34	0.11	0.04	-0.47	0.01	0.54	271 (28.3)
Strategy 2/4* -Ad hoc	-0.84	-0.36	-0.68	-1.70	-0.76	-1.67	-0.34	85 (8.9)
Strategy 3/4 -Market-driven	0.09	-0.47	-0.55	0.35	-0.55	0.17	-0.91	240 (25.1)
Strategy 4/4 -High-profile	0.67	0.14	0.45	0.17	0.91	0.31	0.29	360 (37.7)
3-Clusters (5-Clusters with 2 restrictions)								
Strategy 1/3* -Supplier-based	-0.74	0.17	-0.08	-0.38	-0.54	-0.40	0.33	356 (37.2)
Strategy 2/3* -Market-driven	0.09	-0.47	-0.55	0.35	-0.55	0.17	-0.91	240 (25.1)
Strategy 3/3 -High-profile	0.67	0.14	0.45	0.17	0.91	0.31	0.29	360 (37.7)
2-Clusters (5-Clusters with 3 restrictions)								
Strategy 1/2 -Low-profile	-0.41	-0.09	-0.27	-0.08	-0.54	-0.17	-0.17	596 (62.3)
Strategy 2/2 -High-profile	0.67	0.14	0.45	0.17	0.91	0.31	0.29	360 (37.7)

* denotes the two strategies/clusters that join together in the subsequent stage.

The results begin with the 5-cluster solution. The Supplier-based strategy has high scores specifically on "buy" and "opportunistic", which suggests that these firms mainly rely on suppliers (of machinery and equipment) for their innovation. The Ad hoc strategy refers to the group of firms which has below-average (negative) scores on all factors. This strategy refers to undertaking innovation on an *ad hoc* basis (Winter, 2003), without particular reference to the strategic factors identified. The Market-driven group scores positive on "market" and "industry", and, to a lesser extent, on "make", which implies that firms in this group tend to seek knowledge from the industry for their innovation process, aiming to make more and better products to compete in the market. The R&D intensive strategy represents a group of firms which are active in all of the aspects of innovation considered, but especially stand out with higher scores on both external and internal R&D factors, "make" and "buy". The fifth group is called Science-based innovation strategy, since this group scores particularly high on "science" and "make", i.e. they are firms which utilise scientific knowledge and undertake internal R&D.

In the 4-cluster solution, the Science-based and R&D intensive groups are merged. This combined group (High-profile) still scores higher than average on all factors, but now more substantially on "science". In the next phase (the 3-cluster solution), the Ad hoc group is combined with the Supplier-based group, which, at this point, turns to have negative scores on all factors, except "buy" and "opportunistic". Here, the Supplier-based group seems to refer to firms which depend very little on themselves, but heavily on their suppliers. Finally, the 2-cluster solution distinguishes the High-profile and Low-profile groups of firms. The move to this stage merges the Supplier-based and Market-driven group into one with low scores on all factors, i.e. Low-profile (similar in meaning to the Ad hoc strategy identified above, but not in scale or membership).

The hierarchical nature of the clusters (i.e. at each transition between two levels, two clusters are combined) can, in the econometric context, be represented as being a set of restrictions on the coefficients in the estimated model. For example, the five strategies (clusters) will be represented by five dummy variables (the non-innovators being the reference category). The move to four strategies (clusters) can then be represented by the restriction that two of these dummy variables (R&D intensive and Science based) carry the same coefficient. A similar logic applies to each "transition" to a lower number of strategies (e.g. four clusters is equivalent to five clusters with one restriction, and three clusters is equivalent to five clusters with two restrictions).

5. Econometric Results

The econometric exercise estimates a probit model for two dependent variables, namely, product innovation and process innovation. The first model (Table 7) examines the persistence of innovation by taking into account the lagged dependent variable and initial innovation as a way to account for firm heterogeneity, but does not yet include the innovation strategy variables. This is the model which has been used in the literature so far (e.g. Peters, 2009).

Table 7. Basic model

	Product innovation			Process innovation		
	Coeff.	St. Error		Coeff.	St. Error	
Initial innovation						
(Innovation at t_1)	0.551	0.248	**	0.166	0.162	
Lagged innovation	0.436	0.213	**	0.323	0.171	*
Size	0.277	0.053	***	0.212	0.041	***
Industry dummies		Yes			Yes	
Rho	0.266	0.143	**	0.106	0.134	
BIC	1782.2			1871.6		
No. of Observations	1475			1509		
No. of firms	910			910		
average observation per firm	1.6			1.7		

*, **, *** denote significance at the 10, 5 and 1% level, respectively.

Both forms of innovation appear to be persistent, as indicated by the positive and significant sign of the lagged innovation variable in both cases. In the case of product innovation, the persistence effect is stronger and more significant, and the initial innovation is also significant, which further adds to the persistence result. In terms of process innovation, the initial innovation variable is not significant, and the lagged innovation has a lower estimated coefficient, which is only significant at the 10% level. Firm size is strongly significant in both cases, although the effect of size is weaker (but still sizable and very significant) in the case of process innovation**.** The contribution of unobserved firm heterogeneity to the total variance (rho) is significant in product innovation, in which case it accounts for about a quarter of the total variance.

The study proceeds by including the innovation strategy dummy variables in the equation instead of the initial innovation, in an attempt to account for the strategic differences between the firms which were argued (in Section 2) to be related to innovation probability and innovation persistence. It should be noted that the model of Table 7 is nested in this new specification, since firms which do not engage in innovation activities (at t = 1) will show a zero value on all innovation strategy variables. Therefore, they are the baseline group, as they were in Table 7. One dummy is used for each innovation strategy, so that the specification of Table 7 corresponds to a case in which all of the coefficients of the innovation strategy dummy variables are equal to each other. It should also be noted that, as discussed above, the set of restrictions on the coefficients (applied to the results in Table 8 – 11) is related to the different levels in the hierarchical cluster analysis which was used to identify innovation strategies. In this sense, using less innovation strategies corresponds more closely to the basic specification in the literature.

The reference to such restrictions is useful due to the fact that this study faced a choice about which level of the hierarchical cluster analysis to use. In dealing with this, the study opted to try all cluster solutions (in the range of 2 – 5 clusters), and then chose the one which minimised the Bayesian Information Criterion (BIC) statistic. The BIC is a common criterion used when selecting one from a range of models with a different number of explanatory variables. The results of the “best” model (i.e. with the lowest BIC) are documented in Table 8.

In terms of product innovation, the 5-cluster solution (without any restrictions, i.e. incorporating all of the strategies 1 – 5) minimised the BIC. In other words, the maximum heterogeneity allowed by the model used was found to provide the best fit. This suggests that differences between strategies are an important determinant of product innovation. Such differences appear to have less influence in the case of process innovation, where the model with two strategies (i.e. 3 restrictions: strategy 1 equals strategy 2; strategy 1 equals strategy 3; strategy 4 equals strategy 5) best fits the data. Nevertheless, by comparing the BIC of this model (for process innovation) with the BIC of that in Table 7, 2 strategies are better than no strategies at all.

Table 8. Model with innovation strategy intercepts instead of initial innovation

	Product innovation				Process innovation		
5-clusters (with no restriction)	Coeff.	St. Error		*5-clusters with 3 restrictions*	Coeff.	St. Error	
Lagged innovation	0.423	0.207	**		0.320	0.169	*
Size	0.234	0.050	***		0.191	0.040	***
Strategy 1/5 *Supplier-based*	0.109	0.23					
Strategy 2/5 *Ad Hoc*	-0.951	0.475	**		0.035	0.158	
Strategy 3/5 *Market-driven*	0.621	0.266	**				
Strategy 4/5 *R&D intensive*	1.205	0.341	***		0.331	0.184	*
Strategy 5/5 *Science-based*	0.564	0.270	**				
Industry dummies		Yes				Yes	
Rho	0.226	0.145			0.093	0.134	
BIC	1771.2				1869		
No. of observations	1472				1506		
No. of firms	908				908		
Average observation per firm	1.6				1.7		

*, **, *** denote significance at the 10, 5 and 1% level, respectively.

The results in Table 8 illustrate that both of the estimated coefficients for lagged innovation are still significant. Their value does not differ much from that in Table 7, which implies that the persistence results in Table 7 are robust to the inclusion of strategy variables which measure more firm heterogeneity than does the initial innovation. Despite the inclusion of the innovation strategies, the parts of the total variance explained by unobserved firm heterogeneity (rho) do not decline much. However, unobserved firm heterogeneity no longer contributes significantly to the product innovation equation.

In the case of product innovation, which uses the 5-cluster solution without restrictions, the coefficient of the Supplier-based innovation strategy (mode 1/5) is not significant. Therefore, the firms in this group appear to be at the same baseline innovation probability as the firms which did not innovate in the initial period. The coefficient of the Ad hoc strategy (strategy 2/5), which includes the firms which innovate with minimal inputs, is negative and significant (in the case of product innovation). The negative coefficient indicates that these firms, ceteris paribus, are less likely to innovate than those identified as non-innovators in the initial period. This seems to suggest that this innovation strategy is a one-off innovation, i.e. once these firms innovate, they will not do it again in the next couple of years, because innovative activity is not a strategic element of their behaviour. This could be termed anti-persistence.

The other three strategies for product innovation all show significant and positive coefficients, which indicates that firms with these innovation strategies are more likely to be innovators than those which did not initially innovate. Interestingly, the coefficients for these three innovation strategies differ from each other, with strategy 4/5 (R&D intensive) yielding the highest one. This result supports the point made in the theoretical discussion, i.e. R&D activity was positively related with innovation persistence due to the nature of sunk costs or the increased absorptive capacity related to this type of activity. Overall, the results clearly confirm the hypothesis that different types of innovation strategies lead to different probabilities of innovation, and that this tendency is persistent over the time-scale of the regressions in this exercise. Moreover, a weaker emphasis on the different dimensions of innovation strategies leads to less persistent innovation behaviour.

In terms of process innovation (applying the 5-cluster solution with 3 restrictions), the baseline innovation probability of the first three strategies (Supplier-based, Ad hoc and Market-driven) is not significant (i.e. statistically identical to non-innovators), and for the other two strategies, R&D intensive and Science-based, it is positive, but not very high (the marginal effects will be presented and discussed later). This less-clear persistence in the case of process innovation is consistent with the results in Table 7 (basic model with no innovation strategies).

Table 9. Estimations for high- and low-tech separately (only results with strongest persistence)

	Product innovation, high-tech					
	(Basic Model)			*(5-clusters with 2 restrictions)*		
	Coeff.	St. Error		Coeff.	St. Error	
Initial innovation	0.593	0.319				
Lagged innovation	0.656	0.277	**	0.400	0.280	
Size	0.321	0.093	***	0.292	0.095	***
Strategy 1/5 *Supplier-based* Strategy 2/5 *Ad hoc*				-0.156	0.345	
Strategy 3/5 *Market-driven*				0.988	0.384	***
Strategy 4/5 *R&D intensive* Strategy 5/5 *Science-based*				1.120	0.363	***
Industry dummies		Yes			Yes	
Rho	0.258	0.100	*	0.271	0.088	**
BIC	397.3			391.4		
No. of observations	325			323		
No. firms	192			191		
Average observation per firm	1.7			1.7		
	Process innovation, low-tech					
	(Basic Model)			*(5-clusters with 3 restrictions)*		
	Coeff.	St. Error		Coeff.	St. Error	
Initial innovation	0.059	0.177				
Lagged innovation	0.437	0.189	**	0.432	0.186	**
Size	0.214	0.046	***	0.190	0.044	***
Strategy 1/5 *Supplier-based* Strategy 2/5 *Ad hoc* Strategy 3/5 *Market-driven*				-0.097	0.170	
Strategy 4/5 *R&D intensive* Strategy 5/5 *Science-based*				0.283	0.207	
Industry dummies		Yes			Yes	
Rho	0.028	0.162		0.014	0.158	
BIC	1416.4			1414.2		
No. of observations	1175			1174		
No. firms	720			719		
Average observation per firm	1.6			1.6		

*, **, *** denote significance at the 10, 5 and 1% level, respectively.

Raymond et al. (2006) found different results for persistence in high-tech and low-tech sectors,[5] and this was also tested in the present study. Table 9 reports some estimations in which the model is estimated separately for high-tech and low-tech sectors. The full set of models is not documented (both types of innovation in both sectors), but instead, emphasis is placed on the cases which demonstrate a stronger persistence than those in Tables 7 and 8. These are product innovation in high-tech, and process innovation in low-tech.

Product innovation in the high-tech sector appears to be very persistent if the innovation strategy variables are excluded (i.e. in the 'basic model'). In this case, a coefficient of about 0.66 was found for lagged innovation, which is higher than any coefficient in the previous tables. However, this appeared to be largely spurious, since the coefficient became non-significant and dropped to 0.4 when innovation strategies were included. In terms of process innovation, which is most persistent in the low-tech sector, no such spurious persistence was found. In fact, the innovation strategy variables all appeared to be non-significant in this case. The coefficient for lagged process innovation is about 0.1 higher than in Table 8.

What do these results imply for the relevance of innovation strategies in explaining observed differences in the propensity to innovate between firms? In order to respond to this question, the implied marginal effects of the variables included in the estimates reported above need to be examined. The marginal effects, which were calculated using the predicted probit probabilities, are documented in Tables 10 and 11.

The overall impression is that the (observed) heterogeneity between firms (innovation strategies) plays an important role in explaining innovation probability, especially in explaining product innovation (see Tables 10 & 11). In the case of product innovation in all sectors (Table 10), firms which were initially in innovation strategy 4/5 (R&D intensive) have a 45% higher probability of innovation than those which did not innovate initially, across the entire time span of the regression. The effect of lagged innovation, i.e. the level of innovation persistence which is unexplained by differences in innovation strategies, is 16% (in the innovation strategies model), which is much lower than the innovation strategy 4/5 effect. The 16% effect related to lagged innovation is comparable to the difference between

[5] High-tech and low-tech are defined along the lines of OECD (1999) classification. High-tech consists of chemicals, electrical products, machinery and equipment, plastics and vehicles industries. On the other hand, Low-tech consists of food, metals, non-metallic products, textiles, products not classified elsewhere, and wood.

the marginal effects of innovation strategy 4/5 and either innovation strategies 3/5 (Market-driven) or 5/5 (Science-based). However, it is smaller than the effect of either innovation strategies 3/5, 4/5 or 5/5 individually, and also smaller than the absolute value of the innovation strategy 2/5 effect (Ad hoc, which is -28%). Only in the case of process innovation is the effect of lagged innovation comparable in size to that of the innovation strategies (mode 4/5 and mode 5/5 in Table 10). In the low-tech sector (Table 11), the effect of lagged process innovation (about 15%) is even larger than the effect of innovation strategies. As discussed earlier, this difference between the persistence of product and process innovation may be explained by the fact that process innovation is often undertaken based on learning-by-doing, which may involve less strategic decision-making and technological advancement.

Table 10. Marginal effects of the main variables in the model (initial innovation, innovation strategies)

	Marginal Effect	St. Error		Marginal Effect	St. Error	
Basic model	**Product innovation**			**Process innovation**		
Initial innovation	0.210	0.092	**	0.059	0.057	
Lagged innovation	0.166	0.082	**	0.115	0.063	*
Size	0.105	0.020	***	0.075	0.014	***
Innovation Strategies model						
Lagged innovation	0.162	0.080	**	0.114	0.062	*
Size	0.090	0.019	***	0.067	0.014	***
Strategy 1/5 *Supplier-based*	0.042	0.090				
Strategy 2/5 *Ad hoc*	-0.281	0.091	***	0.012	0.056	
Strategy 3/5 *Market-driven*	0.244	0.102	**			
Strategy 4/5 *R&D intensive*	0.445	0.103	***	0.122	0.069	*
Strategy 5/5 *Science-based*	0.221	0.105	**			

*, **, *** denote significance at the 10, 5 and 1% level, respectively.

Table 11. Marginal effects of the main variables in the model (high-tech, low-tech)

	Product innovation, high-tech					
	Marginal Effect	St. Error		Marginal Effect	St. Error	
Initial innovation	0.223	0.12	*			
Lagged innovation	0.245	0.104	**	0.148	0.105	
Size	0.118	0.034	***	0.106	0.034	***
Strategy 1/5 *Supplier-based*				-0.058	0.131	
Strategy 2/5 *Ad hoc*						
Strategy 3/5 *Market-driven*				0.290	0.083	***
Strategy 4/5 *R&D intensive*				0.369	0.102	***
Strategy 5/5 *Science-based*						

	Process innovation, low-tech					
	Marginal Effect	St. Error		Marginal Effect	St. Error	
Initial innovation	0.02	0.06				
Lagged innovation	0.151	0.069	**	0.15	0.068	**
Size	0.072	0.015	***	0.064	0.014	***
Strategy 1/5 *Supplier-based*						
Strategy 2/5 *Ad hoc*				-0.032	0.056	
Strategy 3/5 *Market-driven*						
Strategy 4/5 *R&D intensive*				0.101	0.075	
Strategy 5/5 *Science-based*						

*, **, *** denote significance at the 10, 5 and 1% level, respectively.

6. Conclusions and Implications for Future Research

An important issue in the recent literature on firm-level innovation is whether, and to what extent, firms which innovate once have a higher probability of innovating again in subsequent periods. Although this phenomenon, which is called ‘innovation persistence’, has been confirmed by many recent studies, none of which has ever empirically investigated why some firms (do not) persistently innovate, and this gap in knowledge is what motivates this study. Based on evolutionary theory and strategic management research, the present study proposes that firm heterogeneity in the form of stable strategic differences across firms can explain why they (do not) persistently innovate. Accordingly, the research question asked was, to what extent do differences in firms' innovation strategies affect their persistence of innovation?

Based on a methodology which combines factor analysis, cluster analysis, and a dynamic random effects probit model, and which extends the Wooldridge method (Wooldridge, 2005) normally used to examine innovation persistence, the study set out to explore this important question in a panel data framework. The results confirm the general finding in the literature that innovation is persistent at the firm level. The most interesting result in this chapter is that observed and stable firm heterogeneity in the form of initial strategic differences across firms constitutes a key driving force behind a firm's probability to innovate over time. The econometric results suggest that the effects of innovation strategies are, in many cases, larger than the 'pure' effect of lagged innovation. This seems to suggest that innovation strategies provide an additional, and more important, source of innovation persistence than lagged innovation.

In addition, this study found that, although there appears to be a sign of persistence of product and process innovation, its significance and scale differ between these two types of innovation. This difference is along the lines of previous research, which has pointed out a distinction between the innovation characteristics of the two types. Differences were also found with regard to innovation persistence in high-tech and low-tech sectors. The results show that the low-tech sector is also persistent in innovation, but mainly in terms of process innovation.

The main contribution of this study to the literature is that it has extended prior research on innovation persistence with the argument that firms have different innovation strategies, and that such strategies constitute an important source of persistent innovative behaviour. Future studies may advance this line of research by showing how the effects of innovation strategies on innovation persistence differ across countries and industries. Future research could also try to better understand why and how firms innovate in one time period but not in subsequent time periods, and why and how firms are able to innovate at one point in time if they have not innovated in the past. This study proposes that initial innovation strategies have a long lasting effect on the way firms conduct innovation. Exploring these and similar questions holds a premise to better understanding firms’ heterogeneity and sources of (persistent) innovation.

References

Aldrich, H. (1999), *Organizations evolving*. SAGE: London.

Argyris, C. and Schon, D. (1978), *Organizational Learning: A theory of action perspective*. Addison-Wesley: MA.

Arora, A., Fosfuri, A. and Gambardella, A. (2001), 'Markets for Technology and their implications for corporate strategy', *Industrial and Corporate Change*, **10(2)**, 419-451.

Arrow, K. (1962), 'The Economic Implications of Learning by Doing', *The Review of Economic Studies*, **29(3)**, 155-173.

Arundel, A., Bordoy, C. and Kanerva, M. (2008), 'Neglected innovators: How do innovative firms that do not perform R&D innovation?', Results of an analysis of the Innobarometer 2007 survey, No. 215, INNO-Metrics thematic paper.

Bodas Freitas, I.M., Clausen, T., Fontana, R. and Verspagen, B. (2008), 'Formal and informal external linkages and firms' innovation strategies: a cross-country comparison', TIK working paper on innovation studies no. 20081113.

Bottazzi, G., Secchi, A. and Tamagni, F. (2008), 'Productivity, profitability and financial performance', *Industrial and Corporate Change*, **17(4)**, 711-751.

Cabral. R. and Leiblein, M.J. (2001), 'Adoption of capital embodied process innovations in industries with learning by doing', *Journal of Industrial Economics*, **49(3)**, 269-280.

Castillejo, M., Rochina Barrachina, M.E., Sanchis Llopis, A. and Sanchis Llopis, J.A. (2004), 'A Dynamic Approach to the Decision to Invest in R&D: The Role of Sunk Costs', Universidad Valencia.

Cefis, E. (2003), 'Is there persistence in innovative activities?' *International Journal of Industrial Organization*, **21(4)**, 489-515.

Cefis, E. and Orsenigo, L. (2001), 'The persistence of innovative activities: A cross-countries and cross-sectors comparative analysis', *Research Policy*, **30(7)**, 1139-1158.

Chesbrough, H., Vanhaverbeke, W. and West, J. (eds.) (2006*), Open Innovation: researching a new paradigm*. Oxford University Press: Oxford.

Cohen, W. and Klepper, S. (1996), 'A reprise of size and R&D', *Economic Journal*, **106**, 925-951.

Cohen, W. and Levinthal, D. (1989), 'Innovation and Learning: the two faces of R&D – implications for the analysis of R&D investment', *Economic Journal*, **99**, 569-96.

Cohen, W. and Levinthal, D. (1990), 'Absorptive Capacity: a new perspective on learning and innovation', *Administrative Science Quarterly*, **35(1)**, 128-152.

Crepon, B. and Duguet, E. (1997), 'Estimating the Innovation Function from Patent Numbers: GMM on Count Panel Data', *Journal of Applied Econometrics*, **12**(Special Issue: Econometric Models of Event Counts), 243-263.

Cyert, R.M. and March, J. (1963), *A behavioural theory of the firm*. Prentice-Hall: NJ.

Dosi, G. (1988), 'Sources, Procedures, and Microeconomic Effects of Innovation', *Journal of Economic Literature*, **26(3)**, 1120-1171.

Dosi, G., Gaffard, J.L. and Nesta, L. (2008), 'Schumpeterian themes on industrial evolution, structural change and their micro foundations: an introduction', *Industrial and Corporate Change*, **17(4)**, 601-609.

Duguet, E. and Monjon, S. (2004), 'Is innovation persistent at the firm level?: an econometric examination comparing the propensity score and regression methods', Université Panthéon-Sorbonne (Paris 1).

Duysters, G. and Hagedoorn, J. (1996), 'Internationalization of corporate technology through strategic partnering: an empirical investigation', *Research Policy*, **25(1)**, 1-12.

Fagerberg, J. (2004) ‘Innovation: A guide to the literature’, in Fagerberg, J., Mowery, D.C. and Nelson, R.R. (eds.) *The oxford handbook of innovation.* Oxford University Press: Oxford.

Flaig, G. and Stadler, M. (1994), ‘Success breeds success: the dynamics of the innovation process’, *Empirical Economics*, **19**, 55-68.

Geroski, P.A., van Reenen, J. and Walters, C.F. (1997), ‘How persistently do firms innovate?’, *Research Policy*, **26(1)**, 33-48.

Grant, R.M. (1996), ‘Toward a knowledge-based theory of the firm’, *Strategic Management Journal*, **17**, 109-22.

Hall, B.H. (2002a), ‘The assessment: Technology Policy’, *Oxford Review of Economic Policy*, **18**, 1-9.

Hall, B.H. (2002b), ‘The financing of research and development’, *Oxford Review of Economic Policy*, **18**, 35-51.

Heckman, J. (1982), ‘Heterogeneity and State Dependence’, National Bureau of Economic Research, Inc.

Helfat, C.E. (1994), ‘Evolutionary Trajectories in Petroleum Firm R&D’, *Management Science*, **40(12)**, 1720-1747.

Hoopes, D.G., Madsen, T. L. (2008), ‘A capability-based view of competitive heterogeneity’, *Industrial and Corporate Change*, **17**, 393-426.

Jensen, M.B., Johnson, B., Lorenz, E. and Lundvall, B.-A. (2007), ‘Forms of knowledge and modes of innovation’, *Research Policy*, **36**, 680-693.

Klepper, S. (1997), ‘Industry Life Cycles’, *Industrial and Corporate Change*, **6(1)**, 145-182.

Laursen, K. and Salter, A. (2006), ‘Open for innovation: The role of openness in explaining innovation performance among U.K. manufacturing firms’, *Strategic Management Journal*, **27(2)**, 131-150.

Leiponen, A. and Helfat, C. (2010), ‘Innovation objectives, knowledge sources, and the benefits of breadth’, *Strategic Management Journal*, **31**, 224-236.

Levitt, B. and March, J.G. (1988), ‘Organizational Learning’, *Annual Review of Sociology*, **14**, 319-340.

Lundvall, B.-Å. (1988), 'Innovation as an Interactive Process: from User-Producer Interaction to National Systems of Innovation', in Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and Soete, L. (eds.), *Technical Change and Economic Theory*. Pinter: London.

Malerba, F. and Orsenigo, L. (1996), ‘Schumpeterian Patterns of Innovation are Technology-specific’, *Research Policy*, **25**, 451-478.

Malerba, F. and Orsenigo, L. (1999), ‘Technological entry, exit and survival: an empirical analysis of patent data’, *Research Policy*, **28(6)**, 643-660.

Mowery, D.C. and Sampat, B.N. (2004), ‘Universities in national innovation systems’, in Fagerberg, J., Mowery, D.C. and Nelson, R.R. (eds.) *The oxford handbook of innovation.* Oxford University Press: Oxford.

Nelson, R.R. (1993), *National innovation systems: a comparative study*. Oxford University Press: Oxford.

Nelson, R.R. and Winter, S.G. (1982), *An Evolutionary Theory of Economic Change*. Harvard University Press: MA.

OECD (1999), *Science, Technology and industry scoreboard: Benchmarking Knowledge-Based Economies*. OECD: Paris.

OECD/Eurostat (2005), *Oslo Manual: guidelines for collecting and interpreting innovation data,* OECD: Paris.

Penrose, E. (1959), *The theory of the growth of the firm*. Wiley: New York.

Peters, B. (2009) 'Persistence of innovation: stylized facts and panel data evidence', *Journal of Technology Transfer,* **34(2)**, 226 – 243.

Pisano, G. (1997), *The development factory: unlocking the potential of process innovation*. Harvard Business Press: MA.

Raymond, W., Mohnen, P., Palm, F. and Van Der Loeff, S.S. (2006), 'Persistence of Innovation in Dutch Manufacturing: Is it Spurious?', CESifo Working Paper No. 1681.

Reichstein, T. and Salter, A. (2006), 'Investigating the sources of process innovation among UK manufacturing firms', *Industrial and Corporate Change*, **15(4)**, 653-682.

Rogers, M. (2004), 'Networks, Firm Size and Innovation', *Small Business Economics*, **22(2)**, 141-153.

Rosenberg, N. (1982), *Insider the black box*. Cambridge University Press: Cambridge.

Schumpeter, J. (1911), *The Theory of Economic Development*. Harvard University Press: Massachusetts.

Schumpeter, J. (1942), *Capitalism, Socialism and Democracy*. Routledge: London.

Smith, K. (2004), 'Measuring innovation', in Fagerberg, J., Mowery, D.C. and Nelson, R.R. (eds.) *The Oxford Handbook of Innovation.* Oxford University Press: Oxford.

Stuart, T. E. and Podolny, J.M. (1996), 'Local Search and the Evolution of Technological Capabilities', *Strategic Management Journal*, **17**(Special Issue: Evolutionary Perspectives on Strategy), 21-38.

Sutton, J. (1991), *Sunk Costs and Market Structure*. MIT Press: MA.

Teece, D.J., Pisano, G. and Shuen, A. (1997), 'Dynamic capabilities and strategic management', *Strategic Management Journal*, **18**, 509-533.

Tushman, M.L. and Rosenkopf, L. (1992), 'Organizational determinants of technological change: towards a sociology of technological evolution', *Research in Organizational Behavior*, **14**, 311-347.

Utterback, J.M. (1994), *Mastering the dynamics of innovation: how companies can seize opportunities in the face of technological change*. Harvard Business Press: MA.

Vega-Juardo, J., Gracia-Guitierrez, A. and Fernandez-De-Lucio, I. (2009), 'Does external knowledge sourcing matter for innovation? Evidence from the Spanish manufacturing industry', *Industrial and Corporate Change*, **18(4)**, 637-670.

Veugelers, R. and Cassiman, B. (1999), 'Make and buy in innovation strategies: evidence from Belgian manufacturing firms', *Research Policy*, **28**, 63-80.

von Hippel, E. (1988), *The sources of innovation*. Oxford University Press: Oxford.

Vonortas, N.S. (1997), *Cooperation in Research and Development*. Kluwer Academic Press: MA.

Winter, S.G. (2003), 'Understanding Dynamic Capabilities', *Strategic Management Journal*, **24(10)**, 991-995.

Wooldridge, J. (2005), 'Simple solutions to the initial conditions problem in dynamic nonlinear panel data models with unobserved heterogeneity', *Journal of Applied Econometrics*, **20(1)**, 39-54.

Chapter 4

ICT, ORGANISATIONAL CHANGE AND GROWTH IN SERVICES[1]

Abstract

This study examines the contribution of Information and Communication Technology (ICT) to a growth in services. Data at the firm level is employed to investigate how ICT as a key technology, combined with non-technological determinants, can influence firm performance. The study develops an argument that ICT is one of the major success factors at the present time, and this particularly holds true in the case of service firms, primarily due to their fundamental characteristics of interactivity and intensity of information, which are highly compatible with this technology. The results indicate that the presence of ICT explains the higher growth in productivity and profitability experienced by firms in the service industries. Growth in services was also found to be significantly linked to the level of ICT intensity in service firms, especially when this intensity is complemented by organisational change. The impact of ICT on service firms is assessed in detail, while manufacturing firms and other innovation activities serve as benchmarks.

[1] The author would like to thank Jan Fagerberg, Bart Verspagen, Marco Vivarelli, Marcela Miozzo, Fulvio Castellacci, Tommy Clausen, Martin Srholec, Caroline Wamala and two anonymous referees at *Structural Change and Economic Dynamics* for very useful suggestions for this research.

1. Introduction

The service sector is now a major component of the global economy, particularly in the majority of developed countries. Evidence reveals that, over the last decade, this sector has accounted for around two-thirds of employment and value added in most industrialised economies. In recent years, therefore, increasing attention has been paid to discovering the driving force behind the successful growth of (most) service industries.

Innovation is seen to be the major driver of economic growth, and a number of studies (for example, Barras, 1990; Evangelista, 2000; Gershuny and Miles, 1983; Miles, 2004) appear to confirm the productive relationship between innovation and the growth of the service industries. In particular, ICT (Information and Communication Technology) is regarded to be an extremely important ingredient in innovation in services in the present era (Castellacci, 2006; Hipp and Grupp, 2005; Tidd et al., 2005). Thus, together with non-technological factors like organisational change (Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000, 2003; Tether, 2005), ICT is often used to explain the outstanding upswing of the service industries, and this chapter attempts to contribute to innovation literature by providing firm-level evidence to support this claim. In order to do so, the analysis employs a unique dataset, obtained from an integration of the Norwegian CIS3 (Community Innovation Survey), R&D (Research and Development) survey and financial accounts data**,** to examine how ICT, combined with organisational change, has affected the growth of service firms in Norway.[2] The main objective of this chapter is specifically to shed light upon: (i) the relationship between ICT and firm-level growth in services; and (ii) the complementarity between ICT and organisational change.

The remainder of the chapter is structured as follows. The second section continues with an outline of relevant theories and main hypotheses. This section also provides an explanation of how ICT may be deemed responsible for the high growth in services, with an emphasis on the compatibility of the characteristics of ICT and services. The section ends with a discussion of prior studies of the impact ICT, as well as organisational change, on economic performance. The third section presents the integrated dataset and variables employed in the analysis. The fourth section explores the role played by ICT and other determinants in driving the growth of

[2] The service industries have played a major role in the Norwegian, as well as most of the OECD economies, during recent decades. See Wolfl (2005) for a detailed account of the service economies of these countries.

service firms by means of descriptive statistics and an econometric exercise. The fifth section provides a summary of empirical findings and ends with some concluding remarks.

2. Theoretical Overview and Prior Studies

2.1. A Note on Innovation in Services

It is widely accepted that the manufacturing sector had long been a major contributor to the world's economy, especially since the first industrial revolution (around the 1840s). However, about half a century ago (around the 1960s), the service sector began to play a more important role, and innovation in services increasingly gained the interest of economists and scholars of technical change (for example, Andersen et al., 2000; Barras, 1986; Metcalfe and Miles, 2000). Attention to innovation in services seemingly became significant in the 1990s, when a number of large research projects on service innovation were launched, and some service industries began to be included in R&D and Innovation Surveys. This growing concern hitherto fostered studies of innovation in services, leading to a better understanding of this research topic. The importance of innovation in services is stressed by many prior studies, such as those by Barras (1986, 1990), Evangelista (2000), Miles (2004) Tether et al. (2001) and Tether (2005). Recent evidence suggests that most services have been active in innovation, and many of them have certainly succeeded in achieving an impressive innovative performance. Some studies also regard innovation in services to have been the main thrust of the "service economy" in recent decades (for example, Fuchs, 1968; Gershuny and Miles, 1983; Stanback, 1979).[3]

Gallouj (2002) classifies literature on service innovation into three main categories: (i) Technological approach, which takes into consideration the introduction and diffusion of new technologies into services, which may have improved their productivity and other performance; (ii) Service-orientated approach, which regards innovation in the manufacturing and service industries as being different, and emphasises the "peculiarity" of services related to, for example, non-technological innovation; and (iii) Integrative approach, which investigates the boundary between goods and services, and develops a framework to bridge the gap between them. Despite the different views of innovation in the service industries, one key agreement seems to have been reached, i.e. service innovation is deemed to be a crucial factor of competitiveness and growth of services (Hauknes, 1998). The present study, which

[3] See also Hauknes (1996) for a discussion on analytic approaches related to the service economy.

looks into the question of how ICT and organisational change may jointly contribute to the superior performance of services, follows the technological approach (for example, see Sirilli and Evangelista, 1998; Soete and Miozzo, 1989), while also taking into account the importance of non-technological innovation, as emphasised in the service-orientated approach. Indeed, the heterogeneity of service activities (across industries) may matter in terms of how different services benefit deferentially from innovation. This is why Soete and Miozzo found it necessary to extend Pavitt's (1984) taxonomy of sectoral patterns of technical change by proposing a specific taxonomy for services, which seriously takes into account the heterogeneous characteristics across these industries. Pavitt's taxonomy, which consists of Science-based, Specialised-suppliers, Scale-intensive and Supplied-dominated industries, places all services into one category (namely, Supplier-dominated). Based on trajectories of innovation in services, Soete and Miozzo's taxonomy suggests that only some service industries are supplier-dominated, for example, health, education, public and social services. Two other groups are, in fact, technology-intensive, and these are Scale-intensive physical network industries and Information network industries (for example, wholesale, transport, communication, insurance and financial services), and Science-based and specialised supplier industries (for example, software and business services).[4] Nonetheless, the importance of ICT is common to the service industries in all of these groups. Miozzo and Soete (2001:163) add that these services are "actively engaged in the development and use of data, communication, and storage and transmission of information", which has a pervasive impact on their economic performance. The next section will attempt to explain why ICT may be seen to have been the driving force behind the superior growth of the service industries over recent decades.

2.2. ICT as a Key Technology for Innovation and Growth in Services

The important question is, why did the phenomenal upswing of the service industries come about only recently? The answer to this may lie in the compatibility of the basic characteristics of these industries and their recent key economic driver, and ICT may be taken into account in this respect, since it has been largely instrumental in information/knowledge transfer and interactive learning in the modern economy throughout recent decades. As is argued by Licht et al. (1999) and Hipp and Grupp (2005), ICT is now the major technology for innovation in services. And the outstanding growth of the service industries may relate to

[4] The service industries in these groups are essentially taken into consideration in the present study. See below.

the fact that their fundamental characteristics are highly compatible with this major technical source of “innovation opportunities” (Dosi, 1988). Miles (2004) points out that services are typically interactive, involving a great deal of communication with suppliers and clients in all phases of service activities. Firms in the service industries are naturally “information intensive”, organising their businesses with a preponderance of communicative and transactional operations, which establishes an “ICT-friendly” atmosphere. This is an atmosphere which seems crucial to innovation in services, because innovation in these industries essentially focuses on adopting ICT to facilitate and improve the enormous interactions involved in most service operations/activities.

Because of its advantageous capabilities to dramatically accelerate communication speed and increase information channels, ICT saves costs while increasing the output and quality of most service productions. This is particularly the case for services, since service productions mainly consist of “information” components, which constitute the ideal breeding ground for service innovation exploiting ICT (Gershuny and Miles, 1983). As pointed out by Evangelista (2000), due to the compatible characteristics of ICT and services, the use of ICT plays a vital role in service firms’ innovation activities, and in boosting their performance. On the basis of ICT, many back-office operations in service firms are able to gain higher efficiency and quality (Miles, 1993). However, the value of ICT to service firms is not only limited to the supply side. Due to a (greater) significance of user-producer interaction (e.g. in service “co-productions”) and customisation in service firms, in contrast to that of standardisation in manufacturing firms (Drejer 2004; Gallouj and Weinstein 1997), ICT enables real time and placeless monitoring of customers’ demands, replacing the old physical information systems (Castellacci, 2006). For instance, ICT reduces the need for front-office staff to interact on a face-to-face basis with customers (Miozzo and Soete, 2001), as in the case of e-banking, e-auction, e-shopping, e-learning, e-booking (of various kinds), to mention but a few. To explain the mechanisms by which ICT leads to the better innovative performance of service firms in recent times, Barras (1986) emphasises the fact that ICT helps to establish a technological platform for new service innovation, as well as significantly improving existing services. In addition, ICT greatly supports and improves service firms’ enormous interactions with suppliers and users, which are, in fact, vital sources of information/knowledge for innovation (von Hippel, 1988; Leonard-Barton, 1995). On the one hand, this line of reasoning attempts to recognise the competitive advantage of an “ICT friendly” atmosphere for service firms, and on the other, points out that ICT plays a major role and is rather indispensible to the innovation activities of these firms. Thus, innovation based on ICT assists service firms in achieving enormous improvements and a superior economic performance. Despite the heterogeneity of service activities across industries discussed earlier, evidence from OECD (2000) for instance, confirms that most services are active in innovation based on ICT, and that they certainly benefit from being so.

Prior research compares ICT with other great innovations of the past, such as the steam engine (1840s-1890s), electricity (1890s-1940s) and the mass production technique (1940s-1990s), which were more conducive to innovation in manufacturing, and in great part, led to its golden age. Built upon Schumpeter's seminal piece (1939) on the long (Kondratiev) wave of technical change, Freeman and Perez (1988) develop the argument that each wave, which they label a "techno-economic paradigm", has a similar pattern over time and comes with, among other things, an introduction and diffusion of new key technologies, which can facilitate a quantum leap in the productivity of an economic system. Freeman and Louca (2002) extend this argument by proposing that, following the fourth wave of technical change (characterised as the age of mass production), which was beneficial exclusively to firms in the manufacturing industries, the fifth techno-economic paradigm turned up, with ICT as a key driver, by the end of the 1990s. This recent paradigmatic change seems to have allowed the service industries to "leapfrog" in terms of both economic forging-ahead and catching-up (Castellacci, 2006). Put simply, for more than a decade, manufacturing has had to take a back seat to services, which have been on the rise, driven chiefly by ICT-enabled mass service production ("mass servuction"[5]), as well as ICT-enabled service innovation.

In the age of mass servuction, ICT appears to be relatively compatible with the fundamental characteristics of service firms, which are interactive and information-intensive, in comparison with those of manufacturing firms which are much related to the production of goods. Although computers can be seen everywhere, the use of ICT is mainly concentrated in service industries (McGuckin and Stiroh, 2001). Evidence from the US, for example, shows that manufacturing is indeed much less ICT-intensive than services (Pilat and Wolfl, 2004). As discussed above, this is largely due to the nature of services which process and diffuse information in abundance (for example, financial services and telecommunications). Therefore, the advance of ICT, which allows more information to be instantly and effectively

[5] The term 'servuction' was used in prior studies to refer to service production when drawing an analogy with (goods) production in manufacturing. See Gallouj and Weinstein (1997) and Miles (2004).

codified and transferred, together with the increasing move into the knowledge economy, has expanded the scope of ICT usage in firms in many of the service industries (Pilat, 2001).

In addition, Pilat (2001) highlights the growing economic importance of ICT in services, e.g. high ICT consumption in service firms and the mounting demand for ICT-intensive services, which in turn, substantially increases the weight of these industries in the economy. The importance of ICT as a major driver of the service economy has been significant, especially throughout the last decade, since it has led to the service industries catching up with, and even outperforming nowadays, the manufacturing industries (OECD, 1996). In the light of this phenomenon, the present study investigates the role played by ICT in enhancing the growth of firms in Norway's service industries (see below).

2.3. Prior Research on the Effect of ICT on Economic Performance

The (positive) impact of ICT investment was not at all significant in aggregate output statistics for a long time (especially before the 1990s), despite decades of great advancement in terms of this technology. This is usually referred to as the "Solow paradox", in accordance with the famous statement made in 1987 by Robert Solow, the Nobel laureate in economics: "you can see the computer age everywhere except in the productivity statistics". However, it can be argued that the productivity paradox may have been, for example, because of problems with the statistics themselves (measurement problems, analytical deficiencies, etc.), and/or because a certain length of time was required before productive gains from ICT could be realised (Pilat et al., 2002).[6] Brynjolfsson and Hitt (1996, 2000) point out that this productivity paradox seems to have disappeared by the early 1990s, and as evidenced (for both manufacturing and services) over recent years, a number of countries have certainly enjoyed impressive economic growth with the aid of ICT. For instance, the results from the US (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000) indicate that output growth revived in the 1990s, and significantly accelerated during the period 1995-2000 due to a sharp increase in ICT capital input throughout the decade. The impact of ICT on aggregate growth was also significant in Australia (Parham et al., 2001), Canada (Armstrong et al., 2002), Korea (Kim, 2002), Finland (Jalava and Pohjola, 2001), the UK (Oulton, 2002) and the Netherlands (van der Wiel, 2001). In addition, Pilat and Wolfl (2004) obtained consistent evidence from their study, which applied a distinction between ICT production and ICT use.

[6] The latter is in relation to the claim that other complementary changes in a firm are also needed so as to allow the best-possible exploitation of ICT. See below.

They examined the role of ICT-producing and key ICT-using industries in explaining overall productivity growth in OECD countries, and found that ICT-producing (manufacturing) industries contributed significantly to the growth of Finland, Ireland, and Korea, whereas ICT-using services in some countries, remarkably the US and Australia, experienced an impressive growth in the second half of the 1990s.

Apart from the aggregate evidence, the impact of ICT on growth has been more importantly recognised on the basis of micro-level data from a number of industrialised countries (OECD, 2003). Most of these studies used a variety of econometric techniques and growth accounting methods to examine samples of firms. For example, Lichtenberg (1995) used production function estimates on business firms, and found that the output contribution of computer systems highly exceeds their capital cost. Black and Lynch (2001) analysed both panel and cross-sectional data for firms in the US and found that, in many industries, an increase in productivity growth is due to employees' use of computers. Gretton et al. (2004) analysed firm-level data from the Australian Business Longitudinal Survey, and found positive, significant links between the use of ICT and growth in both the manufacturing and service sectors. Brynjolfsson and Hitt (1996, 2003), based their analyses on US firm-level data, and reported that ICT has a solid impact on productivity. Hempell et al. (2004) analysed comparable panel data of Dutch and German firms in the service industries, and found that ICT capital deepening and innovation have a complementary impact on productivity.

The foregoing prior research supplies evidence which suggests that ICT plays a central role in supporting the growth and economic performance of all industries, including manufacturing and services. However, the firm-level evidence of the influence of ICT, specifically on the growth of service firms is still scarce, especially in terms of Nordic countries, which in fact, extensively rely upon the use of ICT (Sogner, 2009), and are consistently ranked as being highly innovative (Eurostat, 2008). Therefore, this study is devoted to adding to the literature on innovation in services with some empirical findings on the relationship between ICT and the economic performance of service firms in Norway, a country which has gone from being rather poor to occupying a permanent place in the world's richest list. This is not only driven by the country's tremendously growing oil industry, which provides enormous benefits to the national economy, but also the increasing weight of the service sector in Norway.[7] Smith

[7] In a comprehensive study of innovation in Norway, Fagerberg et al. (2009) explain that the impressive growth of the oil industry in Norway has made both direct and indirect contributions to the national economy. The

(2003) demonstrates that, during recent decades, many service industries in Norway have utilised ICT to a considerable extent, but adds that its economic benefits are still unclear. Thus, this chapter focuses on an analysis of firm growth in the service industries as a consequence of ICT intensity, while adopting manufacturing firms and other technological innovation activities as benchmarks.[8] Organisational change, considered to be an important non-technological determinant, is also taken into account in explaining the growth of service firms, and this will be discussed in greater detail in the following section.

2.4. ICT and Organisational Change as Complementary Factors driving Firm Performance

Prior research points out that technological and non-technological innovation are complementary, i.e. an attempt at technological innovation would meet only limited success unless it was accompanied by organisational change, since they are immensely interdependent (Chandler, 1962; Nelson 1991; see also chapter 5 for a discussion and analysis of this issue). As Bruland and Mowery (2004) argue, technological input alone may not have been able to drive firms and countries to perform well, forge ahead, or catch up with others at different points in time. In fact, organisational innovation has also been an important contributor to the success of firms and countries, from the first industrialisation through different techno-economic paradigms.[9] David (1990) raises the point that factory redesign was a key organisational change which complemented firms' exploitation of electricity more than a century ago. Correspondingly, in the present ICT era, firms may not expect to achieve higher quality products, processes or services by simply plugging in computers (Bresnahan et al., 2002). Although ICT is crucial to firm performance as a "general-purpose technology" (Bresnahan and Trajtenberg, 1995; Carlsson, 2004),[10] a significant contribution of ICT to economic success may only be possible when it is reinforced by complementary organisational change (Brynjolfsson and Hitt, 2003; Milgrom and Roberts, 1990). Therefore, firms should not only focus on the technical dimension of change, but also consider

---

indirect ones, for example, include a very significant market expansion, as a result of the growth and development of this industry, for other industries including a number of services.

[8] Pilat and Wolfl (2004) suggest that, due to the high ICT intensity in services in most OECD countries, the impact of ICT on economic performance may be clearer in these industries than in other parts of the economy.

[9] The term 'organisational innovation' is accorded different meanings by different researchers. In this thesis, it refers to a non- or less-technological, customary, institutional way of changing how a firm organises its works. See a detailed discussion on the use of this term in chapter 2. See also Sapprasert (2009).

[10] Other examples of general-purpose technologies include the steam engine and electricity. These are regarded as technologies which can be widely applied to, and have pervasive effects on, technical and economic developments.

attempting a process of reorganisation (Brynjolfsson and Hitt, 2000; Davenport and Short, 1990). For example, it would be practical to make use of ICT, which facilitates and improves information processing and transfer, in decentralisation and/or task delegation in firms (Brynjolfsson and Mendelson, 1993). Firms may also exploit ICT when reengineering business processes, such as implementing electronic commerce and adopting just-in-time management (Hempell et al., 2004).

With reference to the sectoral technological taxonomy discussed above, Miozzo and Soete (2001) claim that a combination of ICT and organisational change is of advantage to a number of firms in Scale-intensive physical network services and information network services, as well as Science-based and specialised supplier services. For example, in financial services, most of today's major commercial banks offer Internet banking, which both requires and allows, among other things, the centralisation of an automated payment process and real-time operations/transactions. By employing data networks, which enable marketing, sales and claims processing operations to be transacted online, many insurance firms have managed to open up their market and operate in foreign countries. Brynjolfsson and Hitt (2000) and Brynjolfsson et al. (2002) review some case evidence which also underscores this complementarity of technical and organisational change. For instance, Wal-Mart gained huge economic success over the last decade by improving various operations, especially related to its new purchasing method, based on ICT and organisational change. Large suppliers in the healthcare industry, like Baxter, focused on combining the use of ICT with the redesign of their supply arrangements, and significantly benefited from such a combined change, in terms of performance improvement, cost-cutting and time-saving, etc. This complementarity is important, even to firms within the ICT-producing industries. Examples include Dell and Cisco, which managed to increase work efficiency and productivity by complementing computerisation with changes in system and organisational practice.

A series of quantitative studies also support this line of argument by supplying firm-level evidence of the complementary effects of technological and organisational change on firms' productivity and other performance measures (see Brynjolfsson and Hitt, 2000, for a review). For example, Brynjolfsson et al. (2002), using US firm-level data, found that computer capital and (intangible) organisational assets are complementary factors for higher firm productivity. This productive relationship was also corroborated by other studies from the US such as those by Bresnahan et al. (2002) and Brynjolfsson and Hitt (2003). However, similar firm-level evidence outside the US is still scarce. Therefore, the present study takes into account the importance of such non-technological changes to service innovation based on ICT in the Norwegian case. One crucial task in the empirical part is to examine to what extent, if at all, ICT and organisational change have jointly led to the better economic performance of service firms in Norway, as presented below.

3. Data and Variables

A unique firm-level dataset employed in the analysis was obtained from an integration of data from the CIS3 (1999 – 2001), R&D survey (1999 – 2001) and annual financial accounts of firms in Norway (1999 – 2003). The two surveys were combined, i.e. a questionnaire which included questions about R&D activities and (European) CIS3 standard questions about innovation activities was created and distributed by Statistics Norway to a large set of firms in Norway with at least 10 employees. There are two main advantages of using this survey data, the first of which is that the response rate was very high (93 %), resulting in a representative sample (of 3,899 firms). Secondly, the questionnaire was structured in the way which allowed both innovative and non-innovative firms (i.e. firms with and without product/process innovation) to answer all of the questions about R&D activities, unlike many other countries where similar surveys were conducted. This helps to avoid having missing values in the R&D part of the dataset used in this study, i.e. no potential sample selection problem relates to this since the information is available for firms in both groups.

Table 1. Descriptive Statistics for ICT Intensity and Economic Performance Indicators

Variables	Valid N	Minimum	Maximum	Mean	SD
Service firms					
Productivity Growth 2001–2003 (exponential) **GPR0103**	963	-2.64	3.18	0.0328	0.78828
Profitability Growth 2001–2003 (exponential) **GPF0103**	861	-5.09	3.43	0.0713	0.99974
ICT Intensity (%) **ICTINTE**	933	0.00	3.99	0.1100	0.13705
Manufacturing firms					
Productivity Growth 2001–2003 (exponential) **GPR0103**	1,474	-3.82	3.44	0.0662	0.69980
Profitability Growth 2001–2003 (exponential) **GPF0103**	1,213	-4.03	3.96	0.1139	0.93599
ICT Intensity (%) **ICTINTE**	1,343	0.00	3.88	0.0116	0.14615

The pooled dataset initially contained 1,464 service and 1,927 manufacturing firms.[11] However, the sample size decreased, since the analysis was restricted to firms with valid information for calculating important variables such as ICT intensity, labour productivity growth and profitability growth. This means that the firms without such information had to be excluded from the analysis (Table 1 provides descriptive statistics for the three variables). Nonetheless, the resulting sample comprised a total of around 1,800 firms (both innovative and non-innovative), in both service and manufacturing industries. Since it conforms to the European standard for the CIS3 (as set by Eurostat), the Norwegian CIS3 essentially provides this study with a range of information about innovation activities at the firm level, and categorical information such as firm size (in terms of employment) and industrial classification (NACE code). However, some of the CIS3 questions referring to firm-level factors which may also matter to a firm's economic performance could not be used for the analysis (i.e. as control variables), such as because of the content of the questions. For example, the (only) question about mergers in the CIS3 asked if a firm had experienced an increase in turnover between 1999 and 2001 as a result of merger with another firm, or part of it. Based on the firms' answer to this question, the study was unable to identify firms which had merged, but had not achieved a turnover increase.[12] Moreover, due to the interest in both innovative and non-innovative firms (and in avoiding the sample selection problem[13]), the study is deprived of some interesting (censored) variables regarding innovation in firms, which exist only in the case of innovative firms, such as sources of information for innovation, cooperation for innovation, and obstacles to innovation.[14] Nonetheless, apart from the CIS information, the financial accounts of Norwegian firms enable the study to obtain two important economic indicators, namely, productivity and profitability growth.[15] The R&D survey supplies the final key information, namely, ICT intensity.

[11] About 500 firms in other industries, such as agriculture, fishing and mining, were set aside.

[12] A merger (or acquisition) can be important to a firm's productivity/profitability because it usually leads to layoff and other savings. However, the only information provided by the CIS in connection with mergers refers to an increase in turnover due to a merger (yes/no), which cannot be used to measure this occurrence for all firms in the sample.

[13] This is a potential problem when only innovative firms are included in an analysis. Nonetheless, the problem may be dealt with by using, for example, matching estimators or a Heckman (1979) model.

[14] The CIS questionnaire structure allows only innovative firms to answer these detailed questions.

[15] Prior studies also used productivity and profitability growth as proxies for economic performance. See, for example, Krugman (1994), Baldwin and Sabourin (2001), Ball and Moffitt (2001), Oulton (2002).

Prior research measured ICT intensity in several ways, for example, as the share of investment devoted to ICT (Doms et al., 2004), as ICT expenditure per employee (Cainelli et al., 2004; Dunne et al., 2001), and as the share of labour equipped with ICT (Maliranta and Rouvinen, 2004). The present study alternatively applies ICT R&D (Research and Development on ICT) expenditure, between 1999 and 2001, over total expenditure (overall expenses in 2001) of a firm as an explanatory variable for ICT intensity (ICTINTE) in the analysis.[16] Consistent with evidence for most OECD countries (Pilat et al., 2002), detailed statistics (not reported here, but available upon request) show that Norwegian firms in different industries are generally ICT-intensive, i.e. that they demonstrate a good level of ICTINTE. These include service firms in both ICT-producing and ICT-using industries,[17] in particular, Business services, Financial services, Computer-related services and Telecommunications. Put another way, not only ICT producers, but also ICT users, conduct R&D on ICT, for example, as the way to learn how best to exploit this technology. This point supports the application/relevance of this variable to the sampled service (and manufacturing) firms taken into account in the analysis.

In addition, the use of information on ICT R&D in the present study is in accordance with a number of previous works which investigated the relationship between innovation and growth using R&D data.[18] The relevance of R&D may be explained by the fact that many firms invest in R&D, even when the majority of fruitful findings have already spilled out into the public domain (Cohen and Levinthal, 1989). This is because, on the one hand, R&D allows the firm conducting it to gain a first-mover advantage in exploiting the new technology found in-house. On the other hand, the same firm can also become a rapid follower by utilising its "absorptive capacity" accumulated through R&D in order to reap the fruits of spillovers from

[16] The combined Norwegian CIS3 R&D survey included a question asking the sampled firms to estimate the share of different R&D activities including R&D on ICT, and the sum of all these activities equals 100 (%). So, when calculating ICTINTE, if the share of ICT R&D of firm X was 20% and the R&D expenditure of firm X was 10,000 NOK, the numerator for firm X is calculated as (20/100) * 10,000. To adjust for this, the numerator is divided by a firm's total expenditure.

[17] For an explanation of this distinction, see Pilat and Wolfl (2004)

[18] Many of these works followed Solow's (1957) well-known decomposition of economic growth, which raises the importance of factors other than typical inputs like labour and capital which underlie productivity residual (that part of output growth not explained by changes in factor inputs). R&D investment is widely seen to be one of these factors, and analyses of the relationship between R&D and firm performance have considerably contributed to literature on economic growth (See Coe and Helpman, 1995; Griliches, 1988; Grossman and Helpman, 1991). The importance of R&D for growth has also been acknowledged in other research camps, including evolutionary economics and innovation studies broadly defined (for example, Cohen and Levinthal, 1989, 1990; Levin et al., 1985, 1987; Rothwell, 1992).

competitors' innovations (Cohen and Levinthal, 1990). This line of reasoning stresses the point that R&D effort is fundamental to the success of innovation and competitiveness, and that the data of R&D expenditure may thus be deemed to be a viable source to be used when constructing a proxy for ICT intensity.

Non-technological innovation like organisational change, which may complement ICT in elevating firm performance, is also taken into account (see above for a discussion on this factor). In this respect, the analysis makes use of the firm-level data, which has a remarkable advantage in measuring intangible organisational investments. As argued by Brynjolfsson and Hitt (2000), non-technological factors cannot be well captured by traditional macroeconomic measurements. The economic contributions of these factors will be examined at the micro level so as to be more appropriate. This analysis employs five non-technological innovation (explanatory) variables constructed based on the following information on organisational change extracted from the firm-level CIS3 data: (i) strategic innovation (STINNO), which refers to the implementation of a new or significantly changed firm's strategy; (ii) managerial innovation (MNINNO), which signifies an attempt to carry out an advanced management technique within a firm; (iii) organisational innovation (OGINNO), which denotes a significant change in a firm's structure; (iv) Marketing innovation (MKINNO), which represents an the introduction of a new or significantly changed marketing concept/strategy of a firm; and (v) Aesthetic innovation (ASINNO), which indicates a significant change in the aesthetic appearance or design of a firm's product. The variable for each type of organisational change equals 1 if a firm is reported to have undertaken the respective type of change between 1999 and 2001, and 0 otherwise.

In addition, information from the CIS3 regarding product and process innovation (PDINNO and PCINNO) was used to create variables to control for the effects of technological innovation. The variables equal 1 if a firm responds that it introduced the respective innovation between 1999 and 2001, and 0 otherwise. Industry and size dummies are also included in the analysis (IND and SIZE). Industrial classification is based on the standard NACE code associated with each firm. Size classes (Size 1, 2, 3 and 4) are classified based on the CIS3 standard breakdown of firm size (in terms of employment), as well as the distribution of firm size in the sample.[19] The value 1 was assigned to each of these control

[19] Sizes 1, 2, 3 and 4 refer to firms with 10-49, 50-99, 100-249 and 250 employees and over, respectively. Dummies for size classes are used as control variables instead of the actual number of employees (or its

variables if a firm belongs to the respective industry and size class, and 0 otherwise. Finally, the analysis includes two measures for a firm's economic performance, namely, labour productivity growth (GPR0103) and profitability growth (GPF0103). These two dependent variables are calculated as (exponential) growth of sales per employee, and of profit per employee, respectively, between 2001 and 2003 (3-year growth rates).

4. Analysis

4.1. Descriptive Evidence

A descriptive analysis of the role played by ICT in explaining firm performance was undertaken by comparing the growth rates (GPR0103 and GPF0103) of ICT-intensive firms (for which ICTINTE > 0) and non-ICT firms (for which ICTINTE = 0) in services, and of firms (both manufacturing and services) the ICT intensity (ICTINTE) of which was above and below the industrial average between 1999 and 2001. Three questions are raised, as follows: (i) whether, and to what extent, ICT-intensive service firms have shown higher growth rates between 2001 and 2003 relative to non-ICT service firms; (ii) whether, and to what extent, service firms with an ICT intensity above the industrial average have shown higher growth rates between 2001 and 2003, compared with those with a lower ICT intensity; and (iii) whether, and to what extent, the differences in these growth rates between 2001 and 2003 between above-average and below-average ICT intensive firms were higher in the manufacturing or service sector. As suggested by Pilat et al. (2002), it may be interesting in an economic sense to compare the performance of ICT-intensive firms with those which have low or no ICT intensity, since this could help to explain the contribution of ICT to growth.

This exercise begins with a comparison of growth rates of ICT-intensive and non-ICT service firms across firms' sizes and industries (see Table 2). The overall results indicate a higher growth of ICT-intensive service firms in terms of both productivity and profitability (the difference is 0.03 and 0.07 %, respectively). However, it seems that these results are driven by the (higher) growth of larger ICT-intensive service firms. In comparison with the growth of non-ICT service firms between 2001 and 2003, ICT-intensive service firms sized 2, 3 and 4 grew higher (0.09, 0.41, 0.72 %, respectively, in terms of productivity, and 0.12, 0.08, 0.46 %, respectively, in terms of profitability), while the opposite is true in the case of Size 1 firms. When attempting to explain the different results for smaller and larger ICT-intensive

---

logarithmic value) because the study is also interested in the (possible) relationship between medium-sized firms (i.e. size 2 and 3) and their performance (see below).

Table 2. Mean Productivity Growth (GPR0103) and Mean Profitability Growth (GPF0103) of ICT-Intensive and non-ICT Firms in Services

	GPR0103			GPF0103		
	ICT intensive	Non-ICT	Dif.	ICT intensive	Non-ICT	Dif.
Wholesale trade	0.2208	0.0882	0.1326	0.7158	0.1282	0.5876
Sea Transportation	0.7020	0.2045	0.4975	0.4924	0.2272	0.2652
Transportation and travel services	0.0849	-0.0207	0.1056	-0.1129	-0.1365	0.0236
Business services	0.0553	-0.0219	0.0772	0.1964	-0.1341	0.3305
Financial Services	0.1907	-0.0029	0.1936	0.4104	0.3489	0.0615
Insurance and Pension	1.9400	0.3739	1.5661	2.3100	0.0340	2.2760
Computer-related services	0.1354	-0.0139	0.1493	-0.0239	0.0780	-0.1019
Telecommunications	-0.5668	0.5026	-1.0694	-0.2791	0.3929	-0.6720
Firm size classes (employment)						
Size 1	-0.5823	-0.2415	-0.3408	-0.6449	-0.2401	-0.4048
Size 2	0.0960	0.0041	0.0919	0.0329	-0.0840	0.1169
Size 3	0.5777	0.1707	0.4070	0.3802	0.3010	0.0792
Size 4	1.4155	0.6998	0.7157	1.0181	0.5563	0.4618
Total	0.0566	0.0316	0.0250	0.1568	0.0847	0.0721

service firms, it may be argued that smaller firms typically have a lower scale of business and less members/employees, and hence, less interaction and computerisation. It is thus possible that they benefit less from R&D or innovation based on this technology. When compared across industries, the impact of ICT R&D on growth in services is germane to most cases, except for Telecommunications and Computer-related services.[20] This may relate to the fact that Norwegian ICT producers perform rather poorly, especially compared with those in neighbouring countries like Finland and Sweden, despite enormous R&D efforts being undertaken and governmental support being provided for many decades (Sogner, 2009). However, a number of Norwegian firms in other services (i.e. ICT-using industries) seem to

[20] That is, the sampled firms in Telecommunications/Computer-related services which had invested in ICT R&D (between 1999 and 2001) did not experience higher growth (between 2001 and 2003). Pilat and Wolfl (2004) also show that these ICT-producing services played a rather small role in aggregate productivity growth (between 1996 and 2002) in Norway, as well as in several OECD countries. This may be due to differences in the countries' specialisations, i.e. only a few of the countries are specialised/competent in ICT-producing services. These few countries include Finland, Ireland and Germany.

benefit from developments and applications based on ICT,[21] which are derived, to a large extent, from imports.

Table 3. Mean Productivity Growth (GPR0103) and Mean Profitability Growth (GPF0103) of ICT-Intensive Firms (above and below the industrial average)

	Services			*Manufacturing*		
	ICTINTE > Average	ICTINTE < Average	Dif.	ICTINTE > Average	ICTINTE < Average	Dif.
Productivity Growth						
Size 1	-0.4933	-0.8140	0.3207	-0.3348	-0.3155	-0.0193
Size 2	0.1583	-0.3620	0.5203	0.3176	0.0442	0.2734
Size 3	0.8529	0.1168	0.7361	0.3349	0.1537	0.1812
Size 4	1.9276	0.1084	1.8192	1.5568	0.0305	1.5263
Total	0.2051	-0.2942	0.4993	0.3966	0.0643	0.3323
Profitability Growth						
Size 1	-0.3857	-0.8478	0.4621	-0.1959	0.7819	-0.9778
Size 2	0.2005	-0.6321	0.8326	0.6613	-1.0313	1.6926
Size 3	0.4605	0.3546	0.1059	0.1683	0.3393	-0.1710
Size 4	1.8098	0.0386	1.7712	1.6258	0.1874	1.4384
Total	0.3293	-0.1380	0.4673	0.4361	0.1757	0.2604

Note: The industrial average refers to the median of ICT intensity of firms in each industry (e.g. Wholesale trade, Financial services, Telecommunications). The median was used instead of the mean in computing this average in order to avoid the effect of extreme values of outliers.

The results shown in Table 2 suggest that ICT has helped to improve the economic performance of the majority of Norwegian service firms. The evidence reported in Table 3 appears to corroborate this argument, since it reveals that service firms which invested in ICT above the industrial average between 1999 and 2001 enjoyed higher growth in both productivity and profitability between 2001 and 2003, when compared to service firms which invested less in ICT during the same period. It is worth noting that the differences in growth rates are most apparent in the case of larger firms (Size 3 and 4). This corresponds to the above discussion that more interaction in larger firms possibly increases the benefit of adopting ICT, as well as to one standard justification from the Schumpeterian Hypotheses, which proposes that larger firms have a better capacity to innovate and improve their performance (Schumpeter, 1942).[22] Overall, these results for the service industries respond to

[21] The Norwegian insurance business, for instance, has benefited considerably by its extensive use of ICT since the early twentieth century. For a discussion, see Sogner (2009).

[22] A large body of literature on the so-called “Schumpeterian Hypotheses” embraces two contrasting views of the relationship between the size of firms and innovation. One of the two views emphasises the role of small firms,

the second question above, i.e. there is a sign of a positive relationship between ICT intensity and service firms' growth in productivity and profitability. Nonetheless, this is further tested below in regression models, which include control variables.

With regard to the third question, the results in Table 3 demonstrate that growth rates between above-average and below-average ICT-intensive firms, in terms of both productivity and profitability, differ more in services than in manufacturing. On the whole, these differences are almost double (0.50 versus 0.33 %, respectively, for productivity growth and 0.47 versus 0.26 %, respectively, for profitability growth), and they are also consistent when compared across firms' sizes. Highly ICT-intensive firms in the service industries (devotion to ICT above the industrial average) of almost every size were found to have performed better between 2001 and 2003, compared to those in manufacturing. In summary, the descriptive evidence seems to suggest that there is a productive relationship between ICT and services, i.e. the presence and intensity of ICT drive firm growth in terms of productivity and profitability, and the effects are clearer in the service industries than in manufacturing.

4.2. Econometric Analysis

In this section, the impact of ICT on growth rates is further examined in an OLS (Ordinary Least Squares) regression framework with four model specifications. This econometric exercise is in line with Cainelli et al. (2004), who examined how innovation affects the economic performance of Italian service firms. In their study, three variables were used to measure firm performance, namely growth rates of sales, growth rates of employment, and labour productivity calculated as sales per employee. On the explanatory side, different types of innovation activities were used as regressors to determine their effects.

The present study extends the work of Cainelli et al. (2004) by specifically investigating the impact of ICT R&D and/or organisational change (1999 – 2001) on the growth rates (2001 – 2003) of firms in Norway. In doing so, the data has a lag of two years, which seems appropriate when it comes to estimating the contribution of R&D to productivity (Pakes and

---

in that entrepreneurs are capable of introducing (radical) innovation to the market, which may devastate the value of incumbent firms ("creative destruction", Schumpeter Mark I, 1911). The other view stresses the relevance of knowledge and other resources accumulated by large firms, for example, through R&D activities, for their innovation process ("creative accumulation", Schumpeter Mark II, 1942). See Scherer (1980), Kamien and Schwartz (1975, 1982), Cohen and Levin (1989) for reviews.

Schankerman, 1984).[23] For the sake of simplicity and clarity, the method used and the results are both discussed below in a step-by-step manner.

$$Y_1 = a_0 + a_1*ICTINTE + a_2*ORGCHA + a_3*TECHINNO + a_4*SIZE + e_1 \quad (1)$$
$$Y_2 = a_0 + a_1*ICTINTE + a_2*ORGCHA + a_3*TECHINNO + a_4*SIZE + a_5*IND + e_2 \quad (2)$$

Both equation (1) and (2) include the following independent variables: ICTINTE (ICT intensity between 1999 and 2001), ORGCHA (dummies for five types of organisational change between 1999 and 2001, STINNO, MNINNO, OGINNO, MKINNO and ASINNO), TECHINNO (dummies for product and process innovation between 1999 and 2001, PDINNO and PCINNO) and SIZE (dummies for four size classes in terms of employment in 2001), where a_i and e_i represent unknown coefficients and error terms, respectively. The differences between these two equations are that the (1), intended as a benchmark estimation, includes both manufacturing and service firms and uses productivity growth (GPR0103) as a dependent variable (Y_1), while the (2), intended for the study's focus on service firms, controls for service heterogeneity by taking in dummies for industrial classification (IND), and employs both productivity growth (GPR0103) and profitability growth (GPF0103) as dependent variables (Y_2) one at a time (see Table 4 & 5). The analysis takes into account all of the service firms in the sample, which, according to Pilat and Wolfl (2004), represent both major ICT-using services (i.e. wholesale trade, business services, financial services, and insurance) and ICT-producing services (i.e. computer-related services and telecommunications).[24]

Table 4 presents the regression results based on the specification in Equation 1. These results corroborate the descriptive evidence and theories outlined above, which point to the importance of ICT to firm growth, particularly in the service industries. In the case of manufacturing firms, the coefficient of ICT intensity (ICTINTE) is positive (0.184), but not statistically significant. This implies that manufacturing firms may also benefit from ICT, but the evidence is unconfirmed in this case. Contrarily, the coefficient of ICT intensity in service firms is positive and highly significant (0.068 at the 1 % level). In both cases, the coefficients

[23] Brynjolfsson and Hitt (2003) also show that, in the case of ICT, a time lag of more than one year enables the effect of computerisation on productivity and output growth to become more apparent.

[24] The CIS3 in most (European) countries, including Norway, does not cover some important industries. A prime example is the retail industry, which is actually an important component of many economies, especially the US (Triplett and Bosworth, 2004; Betancourt, 2004).

of size dummies are also considered to be consistent with the descriptive statistics provided in the previous section. The econometric results indicate a higher growth in larger firms (especially Size 4, i.e. firms with more than 250 employees). Nonetheless, having checked for multicollinearity,[25] the other variables display unclear effects of product and process innovation (PDINNO and PCINNO),[26] as well as organisational change (STINNO, MNINNO, OGINNO, MKINNO and ASINNO), on productivity growth (GPR0103).[27]

Table 4. Impact of ICT and other Innovation Activities on Productivity Growth (GPR0103) of Manufacturing and Service Firms

	Services	Manufacturing
(Constant)	-0.373*** (.048)	-0.380*** (.040)
ICT intensity		
ICTINTE	0.068*** (.025)	0.184 (.115)
Organisational Change		
STINNO	-0.123* (.071)	0.013 (.049)
MNINNO	-0.007 (.076)	-0.014 (.056)
OGINNO	0.039 (.063)	-0.004 (.047)
MKINNO	0.003 (.067)	0.023 (.051)
ASINNO	-0.124 (.080)	0.067 (.051)
Technological Innovation		
PDINNO	-0.003 (.065)	-0.007 (.060)
PCINNO	0.032 (.074)	0.001 (.060)
Firm size classes (employment)		
Size 1	Ref.	Ref.
Size 2	0.306*** (.065)	0.259*** (.051)
Size 3	0.729*** (.062)	0.606*** (.048)
Size 4	1.257*** (.082)	1.085*** (.071)
No. of Observations	674	1119
R^2	0.331 (.320)	0.230 (.223)

*,**,*** denote significance at the 10, 5 and 1 % level, respectively. Standard errors and adjusted R^2 in brackets

[25] Detailed statistics (not documented here, available upon request) indicate that there is no high correlation among these variables.

[26] It may be the case that product/process innovation also is dependent upon ICT intensity. Nonetheless, this causal relationship is difficult to test on the basis of the data used in this study, since these variables refer to the same time period. For example, to examine the influence of ICT intensity on the rates of organisational change, Hollenstein (2004) estimates an equation in which the variable for ICT intensity is lagged by three years.

[27] It should be mentioned that the coefficients of some types of technological innovation and organisational change are negative (for example, product, strategic and managerial innovation), which implies that these attempts may have a negative influence on firm performance. Although these coefficients are not (sufficiently) significant (i.e. unproven findings), it may be explained that, for example, to implement a new strategy or an advanced management technique might not pay off if organisational members are not ready or have strong inertia (see chapter 5 for more discussion on this). Also, in terms of manufacturing, focusing on (radical) product innovation can waste money and other resources toward the end of the product lifecycle (Utterback, 1994).

Table 5. Impact of ICT and Other Innovation Activities on Economic Performance of Service Firms (GPR0103 & GPF0103)

	GPR0103	GPF0103
(Constant)	-0.371* (.196)	-0.057 (.248)
ICT intensity		
ICTINTE	0.068*** (.026)	0.053** (.026)
Organisational Change		
STINNO	-0.136* (.072)	-0.193** (.095)
MNINNO	-0.002 (.076)	0.076 (.101)
OGINNO	0.028 (.064)	0.071 (.087)
MKINNO	0.006 (.068)	-0.106 (.092)
ASINNO	-0.135* (.082)	-0.127 (.105)
Technological Innovation		
PDINNO	-0.012 (.068)	-0.027 (.096)
PCINNO	0.036 (.075)	0.077 (.101)
Firm size classes (employment)		
Size 1	Ref.	Ref.
Size 2	0.309*** (.066)	0.300*** (.092)
Size 3	0.727*** (.064)	0.743*** (.086)
Size 4	1.242*** (.086)	1.251*** (.117)
Industry dummy		
Wholesale Trade	0.024 (.198)	-0.254 (.252)
Sea Transportation	0.015 (.210)	-0.427 (.269)
Transportation and Travel Services	-0.097 (.201)	-0.359 (.256)
Business Services	0.001 (.201)	-0.290 (.255)
Financial Services	0.144 (.256)	-0.264 (.260)
Insurance and Pension	0.305 (.259)	0.023 (.321)
Computer-related services	0.045 (.201)	-0.217 (.256)
Telecommunications	-0.029 (.244)	-0.323 (.314)
No. of Observations	674	689
R^2	0.338 (.371)	0.227 (.203)

*,**,*** denote significance at the 10, 5 and 1 % level, respectively. Standard errors and adjusted R^2 in brackets

The effect of ICT on service firms in particular is further explored using both productivity growth (GPR0103) and profitability growth (GPF0103) between 2001 and 2003 as dependent variables, and industry dummies as additional variables to control for industry heterogeneity, as specified in Equation 2. Table 5 illustrates the results of this econometric estimation. Again, regardless of the growth indicators employed, the contribution of ICT as a key success factor of service firms seems evident (Evangelista, 2000; Gershuny and Miles, 1983; Miles, 2000). The coefficients of ICT intensity (ICTINTE) are statistically significant in both model specifications (0.068 at the 1 % level and 0.053 at the 5 % level, with productivity growth and profitability growth employed as dependent variables, respectively), while the results of other explanatory variables are all consistent with those in Table 4. In addition, despite (possible) heterogeneous characteristics across (groups of Norwegian) service industries as pointed out by Soete and Miozzo (1989),[28] the study found no clear industry-specific effects (IND) on the growths of service firms. This is the case for both producers and users of ICT in Norway.[29] Table 5 does not appear to provide any (significant) evidence to support the point that the sampled Norwegian firms in different service industries may have grown differentially to a considerable extent, for example, due to service heterogeneity.[30]

The results of the estimates so far suggest, among other things, that ICT explains the growth of service firms in Norway. Nevertheless, since no considerable benefit of organisational change has been found as hypothesised, two additional model specifications are taken into account for a further investigation into the joint contribution of ICT and organisational change to growth. As argued above, these aspects of change could be complementary in levering the growth and competitiveness of a firm (Brynjolfsson and Hitt, 2000, 2003). In this respect, a new variable**,** ORG, is constructed to represent (as a proxy for) the five types of organisational change considered in this study (STINNO, MNINNO, OGINNO, MKINNO and ASINNO), and is used to create an interaction term between ICT intensity and organisational change (ICTINTE*ORG). The value of ORG, which refers to the presence of (any attempts at) organisational change, equals 1 if a firm is reported to have undertaken at least one of the five types of organisational change, and 0 otherwise. ICTINTE*ORG, which refers to the joint effort between ICT R&D and organisational change, is the result of multiplying ICTINTE by ORG. Both of these variables are used in Equation 4, following the works of Brynjolfsson et al. (2002) and Hempell et al. (2004),[31] to examine the joint impact between ICT and organisational change on a service firm's growth. Equation 3, where only ORG is added (and replaces the five separate variables for organisational change – ORGCHA,

[28] Castellacci et al. (2009) classify sixty industries in Norway based on their characteristics related to innovation (for example, innovation expenditures, sources and effects). This classification results in three broad groups of industries, which are science-based, resource-based and low-intensity innovators. ICT-producing services (telecommunications and computer-related services) are in the first group, while the last group includes some key ICT-using services, such as wholesale and financial services.

[29] Pilat and Wolfl (2004) also found that, in Norway, the contributions of both ICT-producing and ICT-using services to aggregate productivity growth between 1996 and 2002 were comparable (i.e. quite small). This may relate to the fact that, for decades, the other (resource-based) industries like oil and gas, and fish-farming have been the most important contributors to growth in the Norwegian case (Fagerberg et al., 2009).

[30] Carrying out separate estimates (split-file analyses) per industry may have provided a more detailed view on the effects of service heterogeneity on firm performance. However, this was not possible for many of the industries since the number of sampled firms per industry is too low.

[31] Brynjolfsson et al. (2002) found that ICT and organisational change are complementary inputs which enhance the performance of US firms, whereas the evidence of Hempell et al. (2004) shows some conflict since the joint impact of ICT and organisational change is unclear in the Dutch case.

which was included in Equations 1 and 2 above), is also taken into consideration for the purpose of comparison (of the two sets of results based on Equation 3 versus Equation 4, see Table 6). Both model specifications employ productivity growth (GPR0103) as a dependent variable (Y_3 and Y_4), and ICTINTE as an explanatory variable, and have the same set of remaining control variables with that in Equation 2 (TECHINNO, SIZE and IND; see above for an explanation of these variables), with a_i and e_i also representing unknown coefficients and error terms, respectively. Equations 3 and 4 are formulated as:

$$Y_3 = a_0 + a_1{*}ICTINTE + a_2{*}ORG + a_3{*}TECHINNO + a_4{*}SIZE + a_5{*}IND + e_3 \quad (3)$$

$$Y_4 = a_0 + a_1{*}ICTINTE + a_2{*}ORG + a_3{*}(ICTINTE{*}ORG) + a_4{*}TECHINNO + a_5{*}SIZE + a_6{*}IND + e_4 \quad (4)$$

The results in Table 6 seem to suggest two main points, which are the contribution of a joint effort between ICT and organisational change, and the consistency of the effects of other factors on growth. The estimate based on the specification in Equation 3 yields results comparable to those in Table 5, i.e. productivity growth is influenced by ICT intensity and size, but not industry heterogeneity (IND), technological innovation (TECHINNO),[32] or organisational change (ORG). However, the results change somewhat when the interaction term, ICTINTE*ORG, is added (see Equation 4). The main difference is that the coefficient of ICT intensity (alone) is no longer very significant (ICTINTE), while the new explanatory variable (ICTINTE*ORG) turns out to exert a significant, positive, larger effect on the productivity growth of service firms (the coefficient of 0.134 at the 5 % level). These results imply that investing jointly in ICT and organisational change may be more beneficial, since this could lead to a better performance of the firm than either of them alone. This is in line with Brynjolfsson et al. (2002), who demonstrate that computerisation and reorganisation combined generate a higher value than the simple sum of their separate contributions. Thus, in order to be successful, service firms may need to be reinforced with a combination of ICT and organisational change (Brynjolfsson and Hitt, 2000, 2003).

[32] As discussed above, service innovation is rather non-technological and intangible, and is largely centred on firms' immense interactions with users and suppliers. The unclear effects of technological innovation on the performance of service firms (based on all of the relevant results presented here, see Table 4, 5 and 6) may be due to the fact that it is difficult, and perhaps problematic, to measure their innovation in terms of a traditional typology like product and process innovation, which is more relevant to the production of goods.

Table 6. Joint Impact of ICT and Organisational Change on Productivity Growth (GPR0103)

	GPR0103	GPR0103
(Constant)	-0.394** (.198)	-0.384* (.198)
ICT intensity		
ICTINTE	0.066*** (.026)	0.042 (.028)
Organisational change and its joint contribution with ICT		
ORG	-0.062 (.054)	-0.065 (.054)
ICTINTE*ORG	-	0.134** (.067)
Technological Innovation		
PDINNO	-0.027 (.078)	-0.040 (.069)
PCINNO	0.027 (.074)	0.035 (.074)
Firm size classes (employment)		
Size 1	Ref.	Ref.
Size 2	0.325*** (.067)	0.312*** (.066)
Size 3	0.737*** (.064)	0.733*** (.064)
Size 4	1.244*** (.085)	1.228*** (.086)
Industry Dummy	Yes	Yes
No. of Observations	674	674
R^2	0.330 (.313)	0.334 (.316)

*,**,*** denote significance at the 10, 5 and 1 % level, respectively. Standard errors and adjusted R^2 in brackets

5. Major Findings and Concluding Remarks

This chapter explores the links between some innovation activities and the economic performance of firms in Norway. The relationship between ICT and the growth of firms in service industries is of major concern, with manufacturing firms and other types of technological innovation involved in the analysis as benchmarks. Organisational change is also taken into consideration to investigate its joint contribution with ICT to the growth of service firms. Put simply, this study is concerned with two specific research interests, which are the relationship between ICT and firm-level growth in services, and the complementarity between ICT and organisational change.

The study found that most ICT-intensive service firms have outperformed non-ICT service firms in terms of both productivity and profitability growth, and those with ICT intensity which exceeded the industrial average have experienced even higher growth rates. The results also demonstrate a wider performance gap between the more-versus-less ICT-intensive service firms, when compared to the case of manufacturing. This is in line with the argument that ICT is one of the major economic driving forces, particularly for service industries, during the current techno-economic paradigm (Castellacci, 2006; Freeman and Louca, 2002;

Gershuny and Miles, 1983). As Evangelista (2000) points out, this phenomenon is largely due to the information-based fundamental characteristics of services, which give ICT a central role in service innovation and thus, help to promote the superior growth of service firms (OECD, 1996).

The econometric results appear to be along the same lines. It is evident from different estimations that there is a positive relationship between ICT and the growth of service firms, whereas this is not confirmed (not statistically significant) in the case of manufacturing. As is commonly argued, a firm's size has an influence on its economic performance, but other technical innovation activities do not show the same consistent contribution to growth as ICT R&D. This finding seems to be consistent with the view that ICT is the most important technology for innovation in services (Licht et al., 1999), while "other technologies are of relatively minor importance" (Hipp and Grupp, 2005:520). More importantly, the study found a complementary effect of ICT and organisational change on a firm, i.e. a firm's performance can be improved even more if these attempts are undertaken jointly. As Bresnahan et al. (2002) point out, it is possible that a firm which has invested heavily in ICT does not benefit from it as much as expected, and this is because ICT necessitates reorganisation. In many cases, it is not ICT alone, but the joint contribution of ICT and organisational change which is a compulsory recipe for true success (Brynjolfsson and Hitt, 2000, 2003; Brynjolfsson et al. 2002).

However, it is important to note that this study has some limitations, and that it may be extended in many ways. Firstly, the study's lack of information of other types of firms' ICT investment, such as ICT training or the employment of workers equipped with ICT skills, should be mentioned. This is important because, in fact, many service firms do not invest in ICT R&D, but rather undertake a range of other innovation activities related to ICT, and gain competitive advantage from these. To include such information in the analysis would have led to more insights into the issue. Moreover, the analysis may then have been extended to examine in greater detail how the joint effort of different types of ICT investment and different types of organisational change affect firm performance. Also, had the analysis been undertaken with somewhat more observations, it could have obtained sufficient information for separate estimates of each industry, which may have yielded a better understanding of the influence of service heterogeneity on economic performance. To extend the study in this way may lead to more meaningful findings. Finally, since the boundary between manufacturing and services is increasingly blurring (for example, a vast number of manufacturing firms nowadays also provide services), it would be interesting to study service innovation which may also take place outside the service industries.

References

Andersen, B., Howells, J., Hull, R., Miles, I. and Roberts, J. (2000), *Knowledge and Innovation in the New Service Economy*. Edward Elgar: Cheltenham.

Armstrong, P., Harchaoui, T. M., Jackson, C. and Tarkhani, F. (2002), 'A Comparison of Canada-US Economic Growth in the Information Age, 1981 - 2000: The Important of Investment in Information and Communication Technologies', Economic Research Paper Series No. 70, Zurich.

Baldwin, J. and Sabourin, D. (2001), 'Impact of the Adoption of Advanced Information and Communication Technologies on Firm Performance in the Canadian Manufacturing Sector', Statistics Canada, Micro-Economic Analysis Division, Ottawa, October.

Ball, L. and Moffitt, R. (2001), 'Productivity Growth and the Phillips Curve', NBER Working Paper No. 8421.

Barras, R. (1986), 'Towards a theory of innovation in services', *Research Policy*, **15**, 161-73.

Barras, R. (1990), 'Interactive innovation in financial and business services: the vanguard of the services Revolution', *Research Policy*, **19**, 215-237.

Betancourt, R. (2004), *The Economics of Retailing and Distribution*. Edward Elgar: Cheltenham.

Black, S. E. and Lynch, L. M. (2001), 'How to Compete: the impact of workplace practices and information technology on productivity', *The Review of Economics and Statistics,* **83(3)**, 434-445.

Bresnahan, T. F. and Trajtenberg, M. (1995), 'General Purpose Technologies: 'Engines of Growth'?', *Journal of Econometrics*, **65**, 83-108.

Bresnahan, T. F., Brynjolfsson, E. and Hitt, L. M. (2002), 'Information Technology, Workplace Organization, and the Demand for Skilled Labour: Firm–Level Evidence', *Quarterly Journal of Economics*, **117**, 339-376.

Bruland, K. and Mowery, D. (2004), 'Innovation through time', in Fagerberg, J., Mowery, D., Nelson, R. (eds.), *The Oxford Handbook of Innovation*, Oxford University Press: Oxford.

Brynjolfsson, E. and Hitt, L. (1996), 'Paradox Lost? Firm-level Evidence on the Returns to Information Systems Spending', *Management Science*, **42(4)**, 541-558.

Brynjolfsson, E. and Hitt, L. (2000), 'Beyond Computation: Information Technology, Organizational Transformation and Business Performance', *Journal of Economic Perspectives*, **14(4)**, 23-48.

Brynjolfsson, E. and Hitt, L. (2003), 'Computing Productivity: Firm-Level Evidence', *The Review of Economics and Statistics*, **85(4)**, 793-808.

Brynjolfsson, E. and Mendelson, H. (1993), 'Information Systems and the Organization of Modern Enterprise', *Journal of Organizational Computing,* **3**, 245-255.

Brynjolfsson, E., Hitt, L. and Yang, S. (2002), 'Intangible Assets: Computers and Organizational Capital', *Brookings Papers on Economic Activity*, 137-198.

Cainelli, G., Evangelista, R. and Savona, M. (2004), 'The impact of innovation on economic performance in services', *Service Industries Journal*, **24(1)**, 116-130.

Carlsson, B. (2004), 'The digital economy: what is new and what is not?', *Structural Change and Economic Dynamics*, **15**, 245-264.

Castellacci, F. (2006), 'Innovation, Diffusion and Catching up in the Fifth Long Wave', *Futures*, **38(7)**, 841-863.

Castellacci, F., Clausen, T., Nas, S. O. and Verspagen, B. (2009), 'Historical Fingerprints? A Taxonomy of Norwegian Innovation', in Fagerberg, J., Mowery, D. C. and Verspagen, B.

(eds.), *Innovation, Path Dependency and Policy: the Norwegian Case*. Oxford University Press: Oxford.

Chandler, A. (1962), *Strategy and Structure*. MIT Press: Massachusetts.

Coe, D. T. and Helpman, E. (1995), 'International R&D Spillovers', *European Economic Review,* **39**, 859-87.

Cohen and Levin (1989), 'Empirical Studies of Innovation and Market Structure', in Schmalensee, R. and Willig, R. (eds.), *Handbook of Industrial Organization, Vol. 2.* Elsevier: the Netherlands.

Cohen, W., and Levinthal, D. (1989), 'Innovation and Learning: The two faces of R&D', *Economic Journal*, **99**, 569-96.

Cohen, W., and Levinthal, D. (1990), 'Absorptive capacity: A new perspective on learning and innovation', *Administration Science Quarterly*, **35(1)**, 128 - 52.

Davenport, T. and Short, J. (1990), 'The New Industrial Engineering: Information Technology and Business Process Redesign', *Sloan Management Review,* **31(4)**, 11-27.

David, P. A. (1990), 'The Dynamo and the Computer: a historical perspective on the modern productivity paradox', *American Economic Review Papers and Proceedings,* **1(2)**, 355-361.

Doms, M., Jarmin, R., and Klimek, S. (2004), 'IT Investment and Firm Performance in U.S. Retail Trade', *Economics of Innovation and New Technology*, **13(7)**, 595-613.

Dosi, G. (1988), 'Sources, procedures and microeconomic effects of innovation', *Journal of Economic Literature,* **26**, 1120-71.

Drejer, I. (2004), 'Identifying innovation in surveys of services: a Schumpeterian perspective', *Research Policy,* **33**, 551-562.

Dunne, T., Foster, L. and Haltiwanger, J. (2001), 'Wage and productivity dispersion in U.S. manufacturing; the role of computer investment', NBER Working Papers No. 7465.

Evangelista, R. (2000), 'Sectoral patterns of technological change in services, economics of innovation', *Economics of Innovation and New Technology*, **9**, 183-221.

Eurostat (2008), *Science, Technology and Innovation in Europe*. Eurostat: Luxemburg.

Fagerberg, J., Mowery, D.C. and Verspagen, B. (2009), (eds.), *Innovation, Path Dependency and Policy: the Norwegian Case*. Oxford University Press: Oxford.

Freeman, C. and Louca, F. (2002), *As Time Goes By: From the Industrial Revolutions to the Information Revolution*. Oxford University Press: Oxford.

Freeman, C. and Perez, C. (1988), 'Structural Crisis of Adjustment', in Dosi G., Freeman, C., Nelson, R., Silverberg, G. & Soete, L. (eds.), *Technical change and economic theory*. Pinter: London.

Fuchs, V. (1968), *The Service Economy.* National Bureau of Economic Research: New York.

Gallouj, F. (2002), *Innovation in the Service Economy: The New Wealth of Nations*. Edward Elgar: Cheltenham.

Gallouj, F. and Weinstein, O. (1997), 'Innovation in Services', *Research Policy,* **26**, 537-556.

Gershuny, J. I. and Miles, I. (1983), *The New Service Economy: the Transformation of Employment in Industrial Societies*. Pinter: London.

Gretton, P., Gali, J. and Parham, D. (2004), 'The effects of ICTs and complementary innovations on Australian productivity growth', in OECD, *The Economic Impact of ICT—Measurement, Evidence, and Implications*. 105-130, OECD: Paris.

Griliches, Z. (1988), 'Productivity Puzzles and R&D: Another Nonexplanation', *Journal of Economic Perspective*, **2**, 9-21.

Grossman, G. M. and Helpman, E. (1991), *Innovation and Growth in the Global Economy*. MIT Press: Massachusetts.

Hauknes, J. (1996), 'Innovation in the Service Economy', STEP Report 7/96, STEP Group: Oslo.

Hauknes, J. (1998), 'Services in Innovation – Innovation in Services', STEP Report 13/98, STEP Group: Oslo.

Heckman, J. (1979), 'Sample selection bias as a specification error', *Econometrica*, **47(1)**, 153-161.

Hempell, T., Van Leeuwen, G. and Van der Wiel, H. (2004), 'ICT, Innovation and Business Performance in Services: Evidence for Germany and the Netherlands', in OECD, *The Economic Impact of ICT—Measurement, Evidence, and Implications*, 131-152, OECD: Paris.

Hipp, C. and Grupp, H. (2005), 'Innovation in the service sector: the demand for service-specific innovation measurement concepts and typologies', *Research Policy*, **34**, 517-535.

Hollenstein, H. (2004), 'Determinants of the adoption of Information and Communication Technologies (ICT) – An empirical analysis based on firm-level data for the Swiss business sector', *Structural Change and Economic Dynamics,* **15**, 315-342.

Jalava, J. and Pohjola, M. (2001), 'Economic Growth in the New Economy', *Information Economics and Policy*, **14(2)**, 189-210.

Jorgenson, D. and Stiroh, K. (2000), 'Raising the Speed Limit: US Economic Growth in the Information Age', OECD Working Papers No. 261.

Kamien, M. I. and Schwartz, N. L. (1975), 'Market Structure and innovation: A survey', *Journal of Economic Literature,* **13(1)**, 1-37.

Kamien, M. I. and Schwartz, N. L. (1982), *Market Structure and innovation.* Cambridge University Press: Cambridge.

Kim, S. J. (2002), 'The Digital Economy and the Role of Government: Information Technology and Economic Performance in Korea', Program on Information Resources Policy (PIRP) Report, Harvard University.

Krugman, P. (1994), 'The Myth of Asia's Miracle', *Foreign Affairs*, **73**, 62-78.

Leonard-Barton, D. (1995), *Wellsprings of Knowledge: Building and sustaining the sources of innovation.* Harvard Business School Press: Massachusetts.

Levin, R. C., Cohen, W. and Mowery, D. C. (1985), 'R&D appropriability, opportunity and market structure: new evidence on some Schumpeterian hypotheses', *American Economic Review Papers and Proceedings*, **75**, 20-24.

Levin, R. C., Klevorick, A. K., Nelson R. R. and Winter, S. G. (1987), 'Appropriating the returns from industrial research and development', *Brookings Papers on Economic Activity*, **3**, 783-831.

Licht, G., Ebling, N. and Niggemann, H. (1999), *Innovation in the Service Sector – Selected Facts and Some Policy Conclusions*. European Commission: Luxembourg.

Lichtenberg, F. R. (1995), 'The Output Contributions of Computer Equipment and Personnel: A Firm-Level Analysis', *Economics of Innovation and New Technology*, **3**, 201-217.

Maliranta, M. and Rouvinen, P. (2004), 'ICT and Business Productivity: Finnish Micro-Level Evidence', in OECD, *The Economic Impact of ICT – Measurement, Evidence, and Implications*, OECD, Paris.

McGuckin, R. and Stiroh, K. (2001), 'Do computers make output harder to measure?', *Journal of Technology Transfer,* **26**, 295-321.

Metcalfe, J. S. and Miles, I. (2000), *Innovation System in the Service Economy. Measurement and Case Study Analysis*. Kluwer: Boston.

Miles, I. (1993), 'Services in the new industrial economy', *Future,* **25**, 653-672.

Miles, I. (2000), 'Services Innovation: Coming of Age in the Knowledge Based Economy', *International Journal of Innovation Management*, **4(4)**, 371-389.

Miles, I. (2004), 'Innovation in services', in Fagerberg, J., Mowery, D.C. and Nelson, R.R. (eds.), *The Oxford Handbook of Innovation*. Oxford University Press: Oxford.

Milgrom, P. and Roberts, J. (1990), 'The Economics of Modern Manufacturing: Technology, Strategy, and Organization', *American Economic Review,* **80(3)**, 551-528.

Miozzo, M. and Soete, L. (2001), 'Internationalization of services: a technological perspective', *Technological Forecasting and Social Change,* **67**, 159-185.

Nelson, R. R. (1991), 'Why do firms differ, and how does it matter?', *Strategic Management Journal*, **12**, 61-74.

OECD (1996), *Employment and growth in the knowledge-based economy*. OECD: Paris.

OECD (2000), *Science, Technology and Innovation in the New Economy*. OECD: Paris.

OECD (2003), *ICT and Economic growth: evidence from OECD countries, industries and firms*, OECD: Paris.

Oliner, S. and Sichel, D. (2000), 'The Resurgence of Growth in the Late 1990s: is Information Technology the Story?', *Journal of Economic Perspectives*, **14(4)**, 3-22.

Oulton, N. (2002), 'ICT and productivity growth in the UK', *Oxford Review of Economic Policy*, **18**, 363-379.

Pakes, A. and Schankerman, M. (1984), 'Rates of obsolescence of knowledge, research gestation lags, and the private rate of research resources', in Griliches (ed.), *R&D, Patents, and Productivity*. University of Chicago Press: Chicago.

Parham, D., Roberts, P. and Sun, H. (2001), 'Information Technology and Australia's Productivity Surge', Productivity Commission Working Paper No. 1681.

Pavitt, K. (1984), 'Sectoral patterns of technical change: towards a taxonomy and a theory', *Research Policy,* **13(6)**, 343-373.

Pilat, D. (2001), 'Innovation and Productivity in Services: State of the Art', in OECD, *Innovation and Productivity of Services*. OECD: Paris.

Pilat, D. and Wolfl, A. (2004), 'ICT Production and ICT Use: What role in Aggregate Productivity Growth?', in OECD, *The Economic Impact of ICT – Measurement, Evidence, and Implications*, OECD: Paris.

Pilat, D., Lee, F. and van Ark, B. (2002), 'Production and use of ICT: A sectoral perspective on productivity growth in the OECD area', OECD Economic Studies No. 35, 47-78.

Rothwell, R. (1992), 'Successful Industrial Innovation: Critical Factors for the 1990s', *R&D Management*, **22(3)**, 221-39.

Sapprasert, K. (2009), 'Acknowledging Organisational Innovation', in Ostreng, W. (ed.), *Confluence: Interdisciplinary Communications 2007/2008*. Centre for Advanced Study at the Norwegian Academy of Science and Letters: Norway.

Scherer, F. M. (1980), *Industrial market structure and economic performance.* Rand McNally: Chicago.

Schumpeter, J. A. (1911), *The theory of economic development.* Harvard University Press: Massachusetts.

Schumpeter, J. A. (1939), *Business Cycle: A theoretical, historical, and statistical analysis of the capitalist process,* 2 volumes. McGraw-Hill: New York.

Schumpeter, J. A. (1942), *Capitalism, socialism and democracy*. Routledge: London.

Sirilli, G. and Evangelista, R. (1998), 'Technological innovation in services and manufacturing: results from Italian surveys', *Research Policy*, **27(9)**, 881-899.

Smith, K. (2003), 'Hva slags økonomiske virkninger har IKT skapt?', in Helge Godø (ed.), *IKT etter dotcom-boblen.* Gyldendal akademisk: Norway.

Soete, L. and Miozzo, M. (1989), 'Trade and development in services: a technological perspective', MERIT Research Memorandum 89-031, MERIT: Maastricht.

Sogner, K. (2009), 'Slow Growth and Revolutionary Change – The Norwegian IT Industry Enters the Global Age, 1970 – 2005', in Fagerberg, J., Mowery, D.C. and Verspagen, B. (eds.), *Innovation, Path Dependency and Policy: the Norwegian Case*. Oxford University Press: Oxford.

Solow, R. (1957), 'Technical Change and the Aggregate Production Function', *Review of Economics and Statistics*, **38**, 312-20.

Stanback, T. M. (1979), *Understanding the service economy: Employment, productivity, location*. John Hopkins University Press: Baltimore.

Tether, B. S. (2005), 'Do services innovation (differently)? Insights from the European Innobarometer Survey', *Industry and Innovation,* **12(2)**, 153-184.

Tether B. S., Hipp, C. and Miles, I. (2001), 'Standardization and Particularization in Services: evidence from Germany', *Research Policy,* **30**, 1115-1138.

Tidd, J., Bessant, J. and Pavitt, K. (2005), *Managing Innovation: Integrating Technological, Market and Organizational Change,* 3rd edition. Wiley: West Sussex.

Triplett, J. and Bosworth, B. (2004), *Productivity in the US services sector: New sources of economic growth.* Brookings Institution Press: Washington DC.

Utterback, J. M. (1994), *Mastering the Dynamics of Innovation.* Harvard Business School Press: Massachusetts.

van der Wiel, H. (2001), 'Does ICT Boost Dutch Productivity Growth?', *CPB Document No. 016*, CPB Netherlands Bureau of Economic Policy Analysis.

von Hippel, E. (1988), *The sources of innovation.* Oxford University Press: Oxford.

Wolfl, A. (2005), 'The service economy in OECD countries', STI working paper 2005/3*,* OECD: Paris.

Chapter 5

DETERMINANTS AND EFFECTS OF ORGANISATIONAL INNOVATION[1]

Abstract

This chapter demonstrates how various factors influence the probability of attempts at organisational innovation and the effects of such innovation. An integrated firm-level dataset obtained from two recent waves of the Norwegian Community Innovation Survey (CIS3 & 4) and firms' financial accounts is used to investigate these factors. An analysis which employed a Heckman two-step estimation to ensure against potential sample selection bias demonstrates that, between 1999 and 2004, Norwegian firms were persistent in organisational innovation, and this persistence raised the (positive) effects of organisational innovation on their performance. In addition, the results indicate that a firm's decision to pursue organisational innovation can be influenced by its past economic performance and the high costs of innovation. The results also reveal that a good share of firms in the sample undertook, and benefitted from, different types of organisational change, and such benefits could increase by means of the complementarity of organisational and technological innovation. In further explaining the rates and consequences of organisational innovation, this study argues that a firm's age and size have different impacts on its decision to undertake organisational innovation and on the effects of such innovation on its performance. The study found some evidence to suggest that older, larger firms are more inclined to make an attempt at organisational change, while, in terms of outcomes, smaller firms are more able to benefit from such an attempt.

[1] The author is grateful to Jan Fagerberg, David Mowery, Bart Verspagen, Fulvio Castellacci, Glenn Carroll, Ed Steinmueller, Tommy Clausen and Martin Srholec for their advice on this work. Many helpful comments received from two anonymous referees at *Industrial and Corporate Change* are also greatly acknowledged.

1. Introduction

Chapter 2 denotes a remarkable increase in scholarly attention devoted to innovation over recent decades (see also Fagerberg, 2004; Fagerberg and Verspagen, 2009). Despite the great importance of organisational innovation, especially in economic 'forging ahead' and 'catching up' at different points in time (Bruland and Mowery, 2004), thus far, technological innovation, such as in the sense of new or significantly changed products and processes, has received much more research interest and been taken into account in a far larger number of (quantitative) analyses, mainly owing to the availability of statistics. Taking advantage of a unique firm-level dataset obtained from an integration of the Norwegian CIS 3 & 4 (Community Innovation Survey) and firms' financial accounts, this study attempts to quantitatively analyse how firms make a decision to undertake, and benefit from, organisational innovation, i.e. non- or less technological innovative change of how firms organise their work (see more description below). Arguably, firms' survival and competitiveness depend greatly upon innovation of this sort, as well as its cooperation with technological innovation in boosting performance (Chandler, 1962; Nelson, 1991).

Nonetheless, organisational innovation and its effects can be influenced by firm heterogeneity and other factors. For instance, a firm's past performance, together with various obstacles it faces, may determine the likelihood of organisational innovation (Cyert and March, 1963; Mohr, 1969), while the effects of such innovation may be elevated by its persistence and (complementary) technological innovation. This chapter investigates the change of 'organisational routines' (Nelson and Winter, 1982) in a firm, and the consequences of this change, by taking account of these and other important determinants, such as the firm's age and size. Put simply, the chapter's main objective is to analyse the factors which explain: (i) the firm's decision to attempt organisational innovation; and (ii) the effects of such innovation on its performance.

The remainder of the chapter is organised as follows. Section 2 gives a note on organisational innovation. Section 3 provides the theoretical background and hypotheses. Section 4 presents the data and method used in this study. Section 5 discusses descriptive statistics and empirical findings from the econometric analysis. Section 6 makes final remarks and concludes the study.

2. A Note on Organisational Innovation

More than half a century ago, Schumpeter (1911, 1942), a famous pioneer of innovation and economic change, presented a broad concept of innovation as being the introduction of new products, new processes, new sources of supply, the exploitation of new markets and new ways of organising business.[2] This broad perspective remains valid today, even though the innovative forms of organisations differ considerably, depending on time, and industrial and institutional contexts (Lazonick, 2004). More importantly, innovation literature suggests that the complementarity of technological and non-technological change is essential. These two aspects of change are greatly interdependent (Freeman, 1995), and their co-evolution is part and parcel of real economic progress (Nelson, 1991). Any effort to implement technological innovation would meet with only limited success unless it was accompanied by organisational change (Chandler, 1962). Bruland and Mowery (2004) point out that, historically, 'organisational' innovations, together with certain key technological innovations, have helped to improve firms' performance and growth in many leading and catching-up countries (for example, the US, Germany and Japan) from the first industrialisation through different 'business cycles' (Schumpeter, 1939).[3] More recent evidence confirms that organisational innovation is also crucial in our time, since it complements a key technological driver like Information and Communication Technology (ICT) in elevating firms' performance and growth (Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000, 2003; Brynjolfsson et al., 2002; see also chapter 4 in this thesis).

It should be noted that this thesis uses the term 'organisational innovation' to refer to a new or significantly changed firm's structure and management method.[4] More specifically, unlike the works of authors such as Damanpour (1991) and Sorensen and Stuart (2000), organisational innovation is defined rather narrowly here as innovative change in a non, or rather less, technological manner to a firm's nature, structure, arrangement, practices, beliefs, rules or norms (see also Pettigrew and Fenton, 2000), which may be subsumed under one of Schumpeter's innovation categories mentioned earlier, namely, "new ways of organising business". This is worth noting because different lines of research apply this term in different

[2] For a good discussion on this notion, see Fagerberg (2003, 2004).

[3] These business cycles are also referred to as 'techno-economic paradigms', such as by Freeman and Perez (1988) and Freeman and Louca (2002). Chapter 4 provides a discussion on this.

[4] This largely corresponds with the CIS4's definition of organisational innovation. See below.

ways.[5] For example, organisational innovation is often more broadly defined in management/organisation studies as an adoption of "any" novelty in an organisation (see, for example, Evan, 1966; Daft, 1978; Damanpour, 1987, 1991; Kimberly and Evanisko, 1981; Teece, 1980),[6] while Edquist et al. (2001), leaving aside product innovation, make a distinction between "technical" and "organisational" process innovation.

As argued above, organisational innovation has received much less attention than the technological aspect of innovation. When looking at the scholarly contributions within the area of innovation studies (see Fagerberg, 2004; Martin, 2008; chapter 2 in this thesis), it may be observed that the majority of prominent works, especially those with an empirical focus, have failed to take into consideration the importance of organisational innovation. This is due, in large part, to the availability of statistics. While technological innovation is, for instance, widely examined by reliance on patent and R&D data, how is it possible to measure organisational innovation, which is less tangible in character? Fortunately, a very recent attempt by the CIS has yielded data which may be used to quantitatively analyse this long-neglected aspect of innovation (see below).

3. Theoretical Background and Hypotheses

A central tenet of evolutionary economics highlights 'organisational routines' as being fundamental ways of doing things in a firm (Nelson and Winter, 1982). As time passes, some of the best practices or prevailing routines in the firm may become less effective or may even be no longer acceptable, especially in comparison with those of competitors (Dosi and Nelson, 1994). Organisational transformation is thus crucial (Romanelli and Tushman, 1994), i.e. old routines need to be replaced by new ones if the firm is not to be driven out of business. Following the adaptation perspective, in order to survive, remain competitive, or co-evolve with industrial dynamics, the firm has to search for better solutions and make changes (Nelson and Winter, 1982; Teece and Pisano, 1998), particularly if its performance falls below its 'aspiration level' or a new window of opportunity opens up (Cyert and March, 1963; Greve, 2003; March and Simon, 1958). Although such routine change is clearly important to all firms, considerable heterogeneity exists among them (Nelson and Winter, 1982), i.e. firms have a variety of characteristics which make them different in how they decide to attempt a

[5] See also a discussion on 'organisational innovation' studies in, for example, Lam (2004) and Sapprasert (2009).

[6] The term "administrative innovation" is used as opposed to "technical innovation" in this line of research.

routine change and benefit from such an attempt. In line with Becker et al. (2005), the concept of 'organisational routine' is applied in the present study to investigate the influence of firm heterogeneity and other factors on the rates and consequences of organisational innovation.

3.1 Performance Feedback and Obstacles

As outlined above, understanding why firms do or do not innovate is an important item on the evolutionary economics research agenda (Nelson and Winter, 1982; Fagerberg, 2003). Just as sunglasses are worn when sunlight is noticed, firms change in response to managers' recognition of problems and of various other changes (Cyert and March, 1963). In particular, variation in performance is one obvious factor which typically induces change in a firm, especially when the manager's or shareholder's aspiration level of performance cannot be achieved (March and Shapira, 1992; Greve, 2003). On the one hand, an unsatisfactory situation, such as low profit, may hinder the firm's decision to engage in an innovation project,[7] which is naturally costly and risky.[8] On the other hand, adaptive learning perspectives suggest that innovation in a firm is more likely when the firm's performance appears to have under-achieved, i.e. past failures drive a firm to change in pursuit of better performance (Cyert and March, 1963; Greve, 1998; Levinthal and March, 1981; Tushman and Romanelli, 1985). Thus, it is argued that a performance shortfall may be an important motive for organisational innovation.

H1: *A decline in growth increases the probability of attempts at organisational innovation*

Moreover, Mohr (1969) points out that the propensity to innovate is determined, not only by managers' or shareholders' motivations, but also by the strength of the obstacles to innovation and the resources available to overcome such obstacles.[9] Clausen (2008) argues that some obstacles or problems perceived by a firm may trigger organisational change. For example, a firm may remedy its lack of funds or skilled workers by changing its structure or business

[7] This also implies that a firm which has made high profits is possibly more inclined to innovate, which corresponds to the idea that "success breeds success". This idea suggests that past commercial success, i.e. profit from successful innovation, may be conducive to financing current and future innovation projects/activities. See Flaig and Stadler (1994), Nelson and Winter (1982) and Chapter 3 in this thesis.

[8] For a review of the literature on the issues related to financial difficulties in funding (risky) innovation and R&D, see Hall (2002a).

[9] From a management perspective, these obstacles to a firm's innovation could be either internal "weaknesses" (Penrose, 1959) or external "threats" (Porter, 1980, 1985).

process, collaborating with other firms, outsourcing, etc. However, due to uncertainty, a lack of important organisational resources is likely to increase a firm's fear of failure, i.e. hinder a firm's risk-taking behaviour (Cyert and March, 1963). Therefore, this problem usually discourages the decision to invest in organisational innovation. Sirilli and Evangelista (1998) and Galia and Legros (2004) provide evidence to support the view that firms commonly consider innovation as being a costly activity, and this places particular pressure on their decision to innovate.

Because a firm never has, and can never obtain, a complete set of perfect information (Nelson and Winter, 1982), the consequences of changing are generally less foreseeable than the consequences of not changing (Greve, 1998). Such obstacles would, therefore, increase managerial reluctance to pursue organisational innovation.

H2: *Managerial perceptions of obstacles decrease the probability of attempts at organisational innovation*

3.2 Persistency and Complementarity

Evidence from recent studies suggests a notion of innovation persistence (although largely in the technological sense), for example, Crepon and Duguet (1997), Flaig and Stadler (1994), Peters (2009).[10] This topic, which is increasingly gaining more interest from innovation research at the firm level, is essentially concerned with a firm's probability to innovate over time (see chapter 3). Based more or less implicitly on a linear view of innovation, innovation persistence can be seen as a result of sunk costs (Sutton, 1991). In this respect, a decision to make (either technological or organisational) innovation investment is naturally one for the long term. Once a firm has taken this decision, it can be expected to innovate persistently. This argument does not contradict the evolutionary view of innovation (Dosi, 1988; Nelson and Winter, 1982). Through this lens, a firm may be seen to be persisting in innovation in the way in which it learns and collects knowledge to further its innovation capability. Because of the cumulative nature of learning itself (Rosenberg, 1976), a firm can continually extend and use this capability to develop new products or processes (Raymond et al., 2006), as well as to improve its organisational routines, at decreasing marginal costs (Amburgey et al., 1993). As

[10] To the author's knowledge, the present study is probably one of the first research attempts which, in part, looks at the topic of persistence of innovation in an organisational aspect. Chapter 3 provides a detailed discussion of research on the topic of persistence of technological innovation, as well as attempting an investigation into this research topic.

Amburgey and Miner (1992) and Kelly and Amburgey (1991) argue, organisational change may be seen to be a self-reinforcing process, which has repetitive momentum.

H3: *Past attempts at organisational innovation increase the probability of (new) attempts at organisational innovation*

Because a change in organisational routines can disrupt reliable performance (Hannan and Freeman, 1984), persistence of organisational innovation may, on the one hand, be disadvantageous and result in decreasing returns on a firm's performance. This particularly holds for a firm which changes too frequently and does not have sufficient time to fix the problems which arise from disruption (Amburgey et al., 1993). On the other hand, innovation persistence may be understood to be a process of 'creative accumulation' (Schumpeter, 1942). This process is fundamental to the success of innovative firms, since knowledge obtained through learning from past innovation(s) can support a new round of innovation. Firms learn (to change) by changing, as in conformity with "learning by doing" (see, for example, Arrow, 1962; Nelson and Winter, 1982; Dosi, 1988). This also means that having changed increases firms' experience with change, which may, in turn, make them more able to routinise change (Kelly and Amburgey, 1991), i.e. to develop a 'modification routine' (Nelson and Winter, 1982; Aldrich, 1999). Hence, persistent organisational innovators are possibly more capable of effectively reorganising repeatedly, and benefiting from doing so. This viewpoint supports the competence-based theory at the firm level (Nelson and Winter, 1982), and implies that persistence of organisational innovation yields dynamic increasing returns.[11] Malerba and Orsenigo (1999), for example, provide evidence to demonstrate that firms which persistently innovate possess a great advantage in being able to consistently improve their performance.

H4: *Persistent organisational innovation increases the effects of (current) organisational innovation on firm performance*

---

[11] Built upon the seminal work of Hannan and Freeman (1984), Amburgey et al. (1993) make a claim from a different perspective that organisational change is likely to reset the organisational clock, i.e. the effective alterations of routines, structure, roles and relationships within the organisation possibly make a firm new once more. Therefore, a firm which has changed previously may have its organisational clock reset and become young again. In line with H8 proposing that a younger firm may benefit more from organisational innovation (see below), this claim supports the idea that past or persistent organisational innovation can increase the effects of current organisational innovation on firm performance.

As was argued above, as well as in Chapter 4, technological and organisational innovation are complementary factors, and together they are crucial to improving firm performance. Their joint contribution has been important for innovative firms since the first industrialisation when the steam engine was a new key technology (Bruland and Mowery, 2004). This joint contribution is still important to the modern economy, in which a vast number of firms are attempting to reorganise their business in order to make the most of new technological opportunities which have arisen from, among other things, the introduction and diffusion of ICT (Bresnahan et al., 2002; Brynjolfsson and Hitt, 2000, 2003; Brynjolfsson et al., 2002). For example, many firms re-engineer their business processes on the basis of ICT, such as switching to electronic commerce. Also, because information processing and transfer can be significantly improved by exploiting ICT, decentralisation and task delegation in firms can be done very efficiently nowadays (Brynjolfsson and Mendelson, 1993). These examples support the argument that a great improvement will be achieved in firm performance if technological and organisational innovation are undertaken together (Chandler, 1962; Nelson, 1991).

H5: *Technological and Organisational innovation have a complementary effect on firm performance*

3.3. Age and Size Effects

One strand of research into organisation places emphasis on the importance of environmental selection (Stinchcombe, 1965; Hannan and Freeman 1977, 1984; Aldrich, 1979, among others). This research strand argues that adaptive change is heavily constrained, and that the adjustment to the dynamics of the environment relies chiefly on the birth and death of the organisation.[12] In particular, Hannan and Freeman's (1984) inertia theory indicates *inter alia* that age and size of firms are associated with a strong force which hinders organisational change. They label this force "structural inertia", and explain that it is a product of the development of the reliability and accountability of firm performance. It can be expected that inertia increases monotonically with age as the firm's working relationships become more formalised, routines become more standardised and the structure becomes more stabilised (Kelly and Amburgey, 1991). Size may also increase inertia because being larger makes the firm more rigid and inflexible (Downs, 1967).

[12] For example, see Levinthal (1991), for a review of the two contrasting, albeit interrelated, perspectives on organisational change: organisational adaptation and environmental selection.

Although firm age and size may increase inertia as the theory suggests, when looking separately at their relationships with: (i) the firm's tendency to attempt organisational innovation, and (ii) the effects of this attempt on the firm's performance, age and size may count differently due to their other properties. Firstly, the age and size of a firm are typically associated with some features which may, instead, trigger efforts at organisational innovation. Kimberly and Evanisko (1981) argue that a firm's size not only necessitates, but also facilitates, its innovative behaviour. Larger firms may be more inclined to undertake organisational change because of their 'deep pockets', i.e. higher level of financial and other resources (Kimberly, 1976; Aldrich and Auster, 1986). In other words, since larger firms generally have a greater capability to innovate (Schumpeter, 1942),[13] they are probably more ready and more likely to do so. Kimberly and Evanisko (1981) and Damanpour (1987) point out that this may hold, not only for innovation in the technical aspect, but also in the organisational dimension.

Furthermore, it is also possible that firm age supports organisational innovation since, compared with the immature or undefined routines of younger firms, the greater maturity of routines in older firms may serve as a powerful impetus for change (Amburgey et al., 1993). While younger firms may be busy dealing with many basic business operational issues which usually arise significantly in the early years (maintaining cash-flow, formalising relationships and so on), or paying more attention to innovating new products and/or processes in order to enter and compete in the market, it can be expected that older firms are relatively less occupied with these aspects, so that their management will have more of a chance to perceive or realise the need for improvements in the organisational structure, management systems/methods, and the like. Thus, the rates of organisational change may increase with firm age.

This line of reasoning suggests that, although organisational age and size are often seen to be associated with inertia, which "often blocks structural change completely" (Hannan and Freeman, 1984:155), this is not always the case, since it also depends on other conditions/circumstances, such as the type of change and environmental dynamics (Hannan and Freeman, 1984). It is possible that "the same forces that make organisations inert also

[13] There is a large body of literature on the so-called 'Schumpeterian Hypotheses' dealing with the issue of how firm size matters to innovation (For example, see Scherer, 1980; Kamien and Schwartz, 1975, 1982; Cohen and Levin, 1989 for reviews). One standard justification for this Schumpeterian tradition is that larger firms have a greater capability to innovate because of their better access to financial resources.

make them malleable" (Amburgey et al., 1993:51), i.e. the age and size of firms have other properties which, as discussed above, may largely induce their decision to undertake organisational innovation.

H6: *Firm age increases the probability of attempts at organisational innovation*
H7: *Firm size increases the probability of attempts at organisational innovation*

Secondly, as Hannan and Freeman (1984) point out, it is difficult to predict the relationship between the age and size of a firm, on the one hand, and the effects of organisational change on the other, particularly when looking at the effects of change on performance. It is possible that the property of inertia, which Hannan and Freeman (1984) suggest is more prevalent in large, old firms, has less of an influence on the firm's tendency to change, but more on the success or effects of change. The present study proposes that the age and size of the firm are more likely to impede the effects of organisational innovation on its performance.

On the one hand, aging is naturally accompanied by the accumulation of skills and knowledge, which is fundamental to innovation processes (Nelson and Winter, 1982), especially in the technological sense. On the other hand, as discussed above, older firms are purported to have more standardised routines and rigid structures (Stinchcombe, 1965; Hannan and Freeman 1984), and because it is more difficult for them to unlearn these routines and transform these structures, many of them remain path dependent (Arthur, 1994; David, 1994). Although, in fact, it is managerial authority which leads to most undertakings/actions in a firm (Witt, 1998; Knott, 2001), in practice, this authority is often subject to limits, especially when it comes to organisational change (Leibenstein, 1987). This implies that older firms, which are usually less adaptive and may be committed to the past, will probably have more difficulty in reaping the benefits of organisational change which has been implemented as strategised.

Also, the effects of organisational change may decrease with the size of the firm, which usually complicates the change process. This complication is mainly due to greater difficulties in coordination in larger firms (Greve, 1999). The size of the firm typically increases the distance between decision makers and practitioners because of a hierarchy, and this distance is likely to vary the commands or plans made (Beckmann, 1977), for example, in connection with reorganisation. Large firms with a structure consisting of many hierarchical levels may, therefore, be less effective at organisational change. In large firms with a lean structure, there are naturally a number of links between each unit, i.e. complexity (Simon, 1962), which, by definition, can also hamper organisational innovation. Moreover, since organisational members usually prefer the *status quo* and thus oppose change, efforts at organisational innovation in larger firms with more people (with any kind of structure) frequently encounter internal opposition or 'political force' (Coch and French, 1948; Pfeffer, 1992). These conditions result in greater ossification and inflexibility, which may cause larger firms to benefit less from attempts at organisational change, if any attempts are made.

In short, despite being factors which may increase the odds of organisational change attempts (H6 and H7, as discussed above), due to their property of inertia, firm age and size are hypothesised as hampering the effects of organisational innovation on firm performance.

H8: *Firm age decreases the effects of organisational innovation on firm performance*
H9: *Firm size decreases the effects of organisational innovation on firm performance*

4. Data, Method and Variables

A unique firm-level dataset from an integration of annual financial accounts (1999 – 2004) and two Norwegian Community Innovation Surveys, CIS3 (1999 – 2001) and CIS4 (2002 – 2004) which include information on 'organisational' innovation, is employed in this analysis. This information, available from the recent waves of CIS, is crucial because it allows issues of organisational change, which are usually scrutinised in a qualitative manner, to be examined quantitatively on the basis of a large-scale database,[14] leading to more generalised findings. The most detailed CIS data is at the firm level. This means that this data can be used to study organisational innovation in individual firms, or can be aggregated for a study at the industry- or country-level, but cannot be broken down to analyse this issue at the plant- or project-level. Therefore, the possibility of some bias in this analysis cannot be denied, for example, larger firms may have a higher probability to report that they are (organisational) innovators based on the data (for example, because they usually have more plants/departments). Nevertheless, when analysing this data, it is not necessarily, and shall not be assumed, that the impact of organisational innovation could be more widespread or noticeable in larger firms simply due

[14] It should be noted that it is only after its second wave (around 1996/1997), that the CIS has placed greater emphasis on non-technological innovation like organisational change by including a section about this issue in the questionnaire.

to their size, since the data provides no information about the scale and number of innovation projects. In other words, some large firms may have introduced just one small innovation project, while some small firms may have introduced many large-scale innovation projects. This is unknown.

Statistics Norway prepared and supplied these CIS and financial data sources. The CIS3 questionnaire was distributed to a representative set of firms registered in Norway with at least 10 employees. 3,899 firms completed and returned the questionnaire, which constituted a high response rate of 93%. This survey was followed three years later by the CIS4, which was also quite successful, judging by its response rate of 95% (receiving responses from 4,655 firms with 10 employees or more). Information on the financial accounts of firms in Norway is collected annually and is available for a large share of these respondents. The three sources were then combined, and the resulting dataset contains around 1,700 respondent firms in the manufacturing, service and other industries (see Table 1). Since this number of firms refers to an overlap of more than 30% of firms from the three sources, the dataset seems to be sufficiently representative.

In order to examine the determinants and effects of organisational innovation on the basis of this integrated dataset, the following two-step model was constructed:

$$\text{ORG} = \text{PASTORG} + \text{PASTPERF} + \text{HAMPi} + \text{SIZE} + \text{AGE} + \text{IND} \quad (1)$$
$$\text{EFORG} = \text{PASTORG} + \text{INCOMP} + \text{SIZE} + \text{AGE} + \text{IND} \quad (2)$$

ORG	= Dummy for the attempt at organisational innovation (2002 – 2004)
EFORG	= Factor score for six types of effects of organisational innovation (2005; see more description below)
PASTORG	= Dummy for the past attempt at organisational change (1999 – 2001)
PASTPERF	= Past performance in terms of profitability growth (1999 – 2001)
HAMPi	= Hampering factors (2002 – 2004; see more description below)
INCOMP	= Dummy for the joint contribution of technological and organisational innovation (2002 – 2004; see explanation below)
SIZE	= Firm size in terms of employment (LogEmp) and turnover (LogTurn)
AGE	= Firm age (LogAge)
IND	= A dummy for industrial classifications (NACE)

Because only those firms which reported to the CIS 4 that they had undertaken organisational innovation between 2002 and 2004 were allowed to answer the question about its effects, i.e. since only organisational innovators are included in equation 2, it is important to inspect for the potential of sample selection bias when analysing this data. Thus, Heckman's (1979) two-step estimate, which can indicate the existence/significance of this bias, is employed (see for example, Zucker et al., 1998; Hall, 2002b; Catozzella and Vivarelli, 2007).[15] Based on this estimate, the selection equation explains whether, and the extent to which, the independent variables included in Stage 1 affect firms' decisions to undertake organisational innovation (ORG), while the outcome equation examines the influence of the independent variables included in Stage 2 on the outcome of such an undertaking (EFORG).

The variables of interest in this Heckman two-step procedure are organisational innovation (ORG), its effects (EFORG), past/persistent organisational change (PASTORG), past performance (PASTPERF), hampering factors (HAMP), the complementarity of organisational and technological innovation (INCOMP), firm size (SIZE), firm age (AGE) and industry dummies (IND). The measure of organisational innovation (ORG), employed as a dependent variable in the selection equation (Stage 1), is obtained from the answers to the question in the CIS4 which asks whether or not, between 2002 and 2004, the firm introduced organisational innovation, defined as being a new or significant change in the firm's structure or management methods seeking to improve the firm's use of knowledge, quality of goods or services, or workflow efficiency. The three types of organisational innovation concerned in the survey are: (i) a new or significantly improved knowledge management system implemented to better use or exchange information, knowledge and skills within the firm (ORGSYS); (ii) a major change to the organisation of work within the firm, such as change in the management structure or the integration of different departments or activities (ORGSTR); and (iii) a new or significant change in the firm's relationships with other firms or public institutions, such as through alliances, partnerships, outsourcing or sub-contracting (ORGREL). Indeed, it is essential to have details of these contents of change, which involve various modifications of elements and interactions within the firm, as well as linkages between the firm and external actors, insofar as the study of organisational transformation is

[15] Since the Heckman results show no sign of selection bias, the OLS (Ordinary Least Square) estimation is also used in the second stage experiment. Three types of organisational innovation (ORGSYS, ORGSTR and ORGREL) are added, in order to examine their potentially differential impacts. See below.

concerned.[16] Based on the three measures, a dependent variable ORG for Stage 1 (Probit) is constructed.[17] ORG equals one if the firm has a positive answer for at least one of the foregoing three types of organisational innovation, and zero otherwise.

The variable used to assess the impact of these three types of organisational innovation is based on the next question in CIS4, which inquired (in 2005) about the effects of such innovation.[18] As mentioned above, only the firms which carried out organisational innovation, i.e. for which ORG = 1, shall respond to the question about its effects. This question asks the firm to rate (from 0 – 3) the importance of six types of effects: (i) reduced response time to customer needs; (ii) improved quality of goods or services; (iii) reduced costs per unit output; (iv) improved employee satisfaction and/or reduced employee turnover; (v) increased enterprise capacity; and (vi) higher enterprise profitability. This information is deemed suitable for use in investigating the effects of organisational change, as it seems to meet the two criteria suggested by Barnett and Carroll (1995), i.e. it captures the effects at the firm level and is broadly applicable (for example, not specific to one or only a few industries or business categories). A factor analysis was conducted for the six measures (see Table A.1 in the Appendix). One factor was retained from this, and the factor score for each firm is used as a dependent variable (EFORG) in the outcome equation, which examines how the effects of organisational innovation are influenced by the predictors included in Stage 2.

Several explanatory variables are employed in the selection and outcome equation. It should be noted that some, but not all,[19] of them are taken into account in both stages. These include PASTORG, used to determine the influence of prior organisational change (between 1999 and 2001) on the probability of another attempt at organisational change by the firm between 2002 and 2004 (ORG) in Stage 1 (testing H3). As explained above, since only the organisational

[16] See Barnett and Carroll (1995) for a good discussion on the process and content of organisational change.

[17] ORG is applied because this Heckman estimation can have only one dependent variable in a binary format (0 or 1) in the selection equation (Stage 1). This means that such a variable (ORG in this case) cannot be a measure of the 'scale' of organisational innovation and, thus, does not (to a great extent) explain its heterogeneity.

[18] It is important to emphasise that, although the information on organisational innovation and its effects both come from the CIS4 (2002 – 2004) which may seem to provide somewhat little time for the effects to be realised and thus have a 'causality' problem, the question on the effects of organisational innovation was designed to be rather explicit by asking the respondent firms to evaluate in 2005 'the effects of organisational innovation introduced' between 2002 and 2004. The Norwegian CIS4 questionnaire was sent out about 6 months after the year of reference (2004).

[19] This is because of a requirement associated with this regression technique (Heckman, 1976, 1979).

innovators between 2002 and 2004 (ORG = 1) are included Stage 2, PASTORG is used also in the outcome equation to assess the extent to which the combined prior and current efforts at organisational change (between 1999 and 2001 and between 2002 and 2004, i.e. persistence of change) increased the effects of organisational innovation felt in 2005, EFORG (testing H4). In other words, this variable, employed in both equations, helps to answer two questions: to what extent were the sampled firms persistent in organisational innovation? And to what extent did those who were benefit more from being so? PASTORG**,** constructed on the basis of the CIS3 data, has a value equal to one if the firm has introduced change between 1999 and 2001 in at least one of the following types related to reorganisation: corporate strategies, management techniques, and organisational structures.

The age and size of a firm, hypothesised to have different impacts on its decision to pursue organisational change and on the effects of such change, are also taken into account in both equations. As Penrose (1959) suggests, firm age and size will be considered as separate determinants of change, since older firms are not necessarily larger than younger firms, and vice versa.[20] Based on the information from the financial accounts, the explanatory variables for firm age and size are created and included in both Stages 1 and 2 (testing H6, H7, H8, H9). Firm age (LogAge) is calculated as the log value of the time period between the year the firm was established and 2001 (the last year before entering the period of main interest, i.e. 2002 – 2004). Firm size is measured on the basis of information about the number of employees (LogEmp) and the firm's total turnover (LogTurn) in 2001.[21] Also, industrial classification dummies (IND), constructed from the CIS3 information, are employed in both stages to control for the influence of industry heterogeneity on the firm's propensity to innovate, as well as on its effects. IND equals one if the firm belongs to the respective industry (classification based on the standard NACE code), and zero otherwise.

PASTPERF & HAMP, hypothesised to affect the firm's decision to undertake organisational innovation (ORG), are included in the selection equation (Stage 1). PASTPERF, measured based on the financial accounts data as firm growth in profitability (profit per employee)

[20] See Table A.2 in the Appendix for a simple correlation test between firm age and size (in terms of both total turnover and number of employees).

[21] Having both of these proxies is advantageous since they possibly explain the size of the firm in different dimensions. That is, while LogEmp is deemed to relate more to the scale of human resource, and may thus better depict a degree of complexity/hierarchy of the firm's structure, LogTurn represents the size of the firm in terms of financial capacity. A simple correlation test conducted shows that turnover does not necessarily very strongly correlate with the number of employees (see Table A.2 in the Appendix).

between 1999 and 2001, captures a recent change in the firm's economic performance which may have some influence on its efforts at organisational innovation (testing H1), since performance variation usually induces the firm to change (Cyert and March, 1963; Greve, 2003). HAMP represents three types of obstacles to organisational change perceived by the sampled firms between 2002 and 2004. These include high innovation costs (HCOST), a lack of funds (HFUND), and a lack of qualified personnel (HPER), which are often regarded as factors which affect innovation in the literature (see for example, Kline and Rosenberg, 1986; Galia and Legros, 2004). Using information from the CIS4, the three proxies are constructed from the firm's rating (from 0 – 3) of the importance of these three impediments to innovation (testing H2).[22]

Finally, since all the firms included in Stage 2 were organisational innovators between 2002 and 2004 (firms with ORG = 1), a dummy for technological innovation in terms of new or significantly improved product(s) or process(es) (INCOMP) between 2002 and 2004 is simply used to measure the joint contribution of technological and organisational innovation in Stage 2 (testing H5), i.e. INCOMP is equivalent to the result of multiplying itself by ORG (which always equals one in this Stage). This variable, applied to examine their interaction/complementarity effect on firm performance (EFORG), is extracted from the CIS4 data on technological innovation, and equals one if the firm introduced at least one product or process innovation between 2002 and 2004. Table A.2 provides a correlation matrix for the explanatory variables employed, with no indication of a multicollinearity problem.

5. Analysis

The descriptive statistics in Table 1 demonstrate that more than one third of the firms in the sample are organisational innovators (having introduced at least one type of organisational innovation between 2002 and 2004).[23] Firm size, in terms of either total turnover or number of employees, seems to have a positive relationship with the rate of organisational innovation since, in comparison with the case of smaller firms, a higher percentage of larger firms

[22] These three variables were selected on the basis of their relevance to organisational innovation (those related only to technological innovation were excluded, for example, a lack of information on technology and an uncertain demand for innovative goods and services), their significance during models tests, and their uniqueness reported in the results of the factor analysis (not reported here; available upon request).

[23] Organisational innovator is defined, in accordance with CIS4's definition of organisational innovation, as a firm which has implemented new or significant change in its structure or management methods in order to improve the firm's use of knowledge, quality of goods and/or services, or efficiency of work flows.

reported that they were organisational innovators (supporting H7),[24] while whether or not firm age monotonically increases this rate is less clear-cut and has yet to be further examined (H6).[25] In terms of the descriptive picture of heterogeneity of organisational innovation (the three measures of organisational innovation obtained from the CIS4), change in the firm's structure (ORGSTR) is the most common, followed by change in the firm's knowledge management systems (ORGSYS) and change in the firm's external relations (ORGREL) respectively, regardless of the firm's age, size and sector. The results from Table 1 also show that only a small share of firms undertook all of the changes considered.

Table 1. Firms' age, size, sector and organisational innovation (2002-2004)

	No. of firms	Organisational innovator	ORGSYS	ORGSTR	ORGREL	1 type of change	2 types of change	3 types of change
Sector								
Manufacturing	947	0.35	0.18	0.28	0.12	0.16	0.15	0.03
Services	580	0.37	0.20	0.28	0.15	0.17	0.13	0.07
Others	210	0.29	0.17	0.22	0.09	0.14	0.12	0.03
Age								
Age1	557	0.41	0.22	0.32	0.16	0.18	0.16	0.07
Age2	591	0.32	0.14	0.25	0.11	0.17	0.12	0.03
Age3	589	0.33	0.19	0.25	0.12	0.14	0.16	0.03
Size								
Emp1	611	0.27	0.14	0.20	0.09	0.13	0.10	0.03
Emp2	477	0.32	0.17	0.23	0.10	0.17	0.10	0.04
Emp3	649	0.46	0.23	0.37	0.18	0.19	0.21	0.06
Turn1	585	0.28	0.14	0.20	0.09	0.14	0.11	0.03
Turn2	589	0.33	0.16	0.25	0.10	0.18	0.11	0.04
Turn3	563	0.46	0.25	0.37	0.19	0.17	0.22	0.07
Total	1,737	0.35	0.18	0.27	0.13	0.16	0.14	0.04

[24] As mentioned above, the CIS data at the firm level as used in this study is the most detailed available. Thus, the study cannot empirically elaborate a detailed relationship, for example, between the number of departments or plants, which are commonly greater in larger firms, and the probability of attempts at organisational innovation.

[25] Age & Size classifications are based on the samples distribution: Age1 = 1-14, Age2 = 15-24, Age3 = 25 years old and over; Emp1 = 10-49, Emp2 = 50-109, Emp3 = 110 employees and over; Turn1 = 1-49,999, Turn2 = 50,000-199,999, Turn3 = 200,000 NOK and over.

Table 2. Firms' age, size, sector, organisational and technological innovation

	No. of firms	Organisational innovator (2002-2004)	Past Organisational Change (1999-2001)	Organisational Innovation Persistence (1999-2001 & 2002-2004)	Technological Innovation (2002-2004)
Sector					
Manufacturing	947	0.35	0.50	0.23	0.54
Services	580	0.37	0.55	0.24	0.42
Others	210	0.29	0.50	0.19	0.26
Age					
Age1	557	0.41	0.57	0.28	0.49
Age2	591	0.32	0.48	0.19	0.46
Age3	589	0.33	0.50	0.22	0.45
Size					
Emp1	611	0.27	0.46	0.16	0.41
Emp2	477	0.32	0.46	0.21	0.48
Emp3	649	0.46	0.61	0.31	0.51
Turn1	585	0.28	0.44	0.17	0.42
Turn2	589	0.33	0.49	0.20	0.47
Turn3	563	0.46	0.63	0.32	0.51
Total	1,737	0.35	0.52	0.23	0.47

Table 2 contains the descriptive statistics of a few other variables in the dataset. The results demonstrate that more than fifty percent of the firms had carried out organisational change between 1999 and 2001, and many of these had made another attempt at organisational change between 2002 and 2004 (supporting H3). Contrary to, for example Geroski et al. (1997) and Cefis and Orsenigo (2001), who found a rather low persistence of technological innovation based on their analyses using patent information, almost one quarter of the sampled Norwegian firms were persistent in organisational innovation between 1999 and 2004. However, the present study finds that technological innovation (product/process) was more common than organisational innovation within the sample between 2002 and 2004 (47 percent of the firms reported undertaking technological innovation, compared with the 35 percent which adopted organisational innovation). When comparing across sectors, it can be seen that a greater share of manufacturing firms engaged in technological innovation, while a greater share of service firms were active in organisational innovation between 2002 and 2004, which is, in fact, reassuring.[26] Finally, despite inconclusive evidence of the influence of firm age, a higher percentage of larger firms, compared with smaller firms, were persistent organisational innovators (i.e., engaged in organisational innovation during both of the time

[26] As usually argued in the literature on service innovation (for example, Evangelista, 2000; Miles, 2004; see also chapter 4 in this thesis), non-technological and intangible characteristics of services are very significant and particularly linked to organisational change.

periods under review), and were innovative between 2002 and 2004 in the technological, organisational sense. The latter point is consistent, for example with Kimberly and Evanisko (1981), which indicates a positive relationship between the size of a firm and its rate of technological and organisational innovation.

The results of the econometric analysis are displayed in Table 3. Firstly, considering the lower part of the first two columns (model I with LogEmp & model II with LogTurn), the Heckman Stage 1 (with ORG as a dependent variable) results provide some evidence of persistence of organisational innovation in line with the descriptive statistics in Table 2 and recent studies, such as Crepon and Duguet (1997) and Peters (2009). Prior organisational change between 1999 and 2001 influenced the probability of another attempt by firms between 2002 and 2004 (ORG), which supports H3. This can be seen from the significant positive coefficients of PASTORG (Past Organisational Change) in models I and II (0.832 and 0.794 respectively, both significant at the 5% level). The results of Heckman Stage 1 also demonstrate the impacts of past performance and hampering factors on the firm's decision to undertake organisational innovation (Cyert and March, 1963; Greve, 1998). The negative coefficients of PASTPERF in both models I and II (-1.513 and -1.488 respectively, both significant at the 10% level) corroborate H1, i.e. attempts at organisational innovation between 2002 and 2004 (ORG) seem to follow a decline in profitability growth (between 1999 and 2001). Nonetheless, the only innovation impediment which is sufficiently significant as a factor to discourage efforts of organisational innovation is the high reported costs of innovation, the negative results of which are significant at the 10% level in both models I and II (coefficients of -0.493 and -0.482 respectively), providing partial support for H2.[27] Having controlled for the influence of age and size, the results seem to support H6, but not H7, i.e. while the (positive) effect of size on the change attempt is not confirmed by the econometric analysis,[28] the evidence suggests that firm age increased the chance of organisational innovation between 2002 and 2004 (ORG), as the coefficients of firm age (LogAge) are positive (0.581 and 0.585) and statistically significant at the 5% and 10% level in models I and II respectively. This is consistent with the above argument that the more mature routines in older firms may

[27] This evidence contradicts that of Veugelers and Cassiman (1999). Using Belgian manufacturing firm data, they found that high innovation costs perceived by firms do not discourage (technological) innovation attempts.

[28] Firm size is however consistently reported to positively influence the rate of organisational innovation in the descriptive part. See Table 1 & 2.

make them more ready, and more likely, to adopt organisational change (Amburgey et al., 1993).

Table 3. Factors explaining organisational innovation and its effects

	EFORG (Heckman 2-stage)		EFORG (OLS estimation)	
	(I) LogEmp	(II) LogTurn	(III) LogEmp	(IV) LogTurn
Constant	-0.235 (0.876)	0.007 (0.899)	-1.387 (0.860)	-1.038 (0.878)
Persistent Organisational Change (PASTORG)	0.129* (0.078)	0.132* (0.078)	0.095 (0.075)	0.099 (0.075)
Complementarity (INCOMP)	0.146* (0.080)	0.154** (0.080)	0.159** (0.079)	0.169** (0.079)
Firm Size				
-*Number of Employees* (LogEmp)	-0.028 (0.030)	-	-0.059** (0.030)	-
-*Total turnover* (LogTurn)	-	-0.035 (0.023)	-	-0.056*** (0.023)
Firm Age (LogAge)	-0.009 (0.055)	-0.004 (0.054)	-0.010 (0.051)	-0.004 (0.051)
Industry Dummies (IND)	Yes	Yes	Yes	Yes
Organisational Innovation (in OLS only)				
-*ORGSYS*	-	-	0.395*** (0.074)	0.397*** (0.074)
-*ORGSTR*	-	-	0.711*** (0.088)	0.712*** (0.088)
-*ORGREL*	-	-	0.199*** (0.074)	0.199*** (0.074)
Selection Equation – Heckman Stage 1 (dependent variable = **ORG**)	--------------	--------------	----------------	----------------
Past Organisational Change (PASTORG)	0.832** (0.375)	0.794** (0.380)	-	-
Profitability Growth (PASTPERF)	-1.513* (0.792)	-1.488* (0.798)	-	-
Hampering Factors (HAMP)				
-*High Innovation Costs* (HCOST)	-0.493* (0.258)	-0.482* (0.256)	-	-
-*Lack of Funds* (HFUND)	0.364 (0.232)	0.374 (0.234)	-	-
-*Lack of Qualified Personnel* (HPER)	-0.145 (0.212)	-0.174 (0.215)	-	-
Firm Size				
-*Number of Employees* (LogEmp)	-0.025 (0.138)	-	-	-
-*Total turnover* (LogTurn)	-	0.067 (0.106)	-	-
Firm Age (LogAge)	0.581** (0.324)	0.585* (0.326)	-	-
Industry Dummies (IND)	Yes	Yes	-	-
Mills ratio	0.293 (0.567)	0.277 (0.563)	-	-
Wald-Test	591.52***	429.58***	-	-
$\mathbf{R^2}$	-	-	0.180	0.184
Number of Observations	1737	1737	597	597
Uncensored	597	597	-	-

*,**,*** denote significance at the 10, 5 and 1 % level, respectively. Standard errors in brackets.

Further, the results in Table 3 shed light on how the effects of organisational innovation (EFORG) can be explained by several determinants. Since there is no clear evidence of selection bias (insignificant Mills ratios in both Heckman models I & II), the results of both the Heckman outcome equation (Stage 2 – the upper part of the results for models I and II) and OLS (Ordinary Least Square) estimations (models III and IV in the last two columns), which are quite comparable, are reported and discussed. Firstly, the results of the Heckman outcome equation (coefficients of 0.129 and 0.132, both significant at the 10% level in models I and II respectively)[29] indicate the existence of a positive relationship between persistence of organisational innovation (PASTORG) and firm performance (EFORG). This supports H4 and prior research such as that undertaken by Malerba and Orsenigo (1999), suggesting that innovation persistency is conducive to the consistent improvement of firm performance. Next, the results of all models in Table 3 confirm H5 in terms of the complementarity effect. The coefficients of INCOMP, measuring the complementarity of organisational and technological innovation, are positive and statistically significant at the 10% level in model I (coefficient of 0.146) and at the 5% level in models II, III and IV (coefficients of 0.154, 0.159 and 0.169 respectively), supporting the claim that this combined presence helps to improve firm performance (Chandler, 1962; Nelson, 1991).

With regard to the size effect, the OLS results (coefficients of -0.059 and -0.056, significant at the 5% and 1% level in models III and IV respectively) provide some support for H9, i.e. larger firms (measured in terms of either employment or turnover) benefit less from reorganisation, possibly due to a range of inertia properties associated with firm size, for example, hierarchy, complexity, political force, as pointed out above.[30] However, none of the models concerned provides clear evidence to support H8. The coefficients of firm age are negative but not statistically significant, i.e. older firms do not appear to benefit differentially from organisational innovation as hypothesised. As the literature suggests, the unclear effect of firm age may be because, on the one hand, older firms are generally associated with stronger structural inertia which hampers change (Hannan and Freeman, 1984). However, these firms may have a higher competency for change and many other activities, having

[29] Nonetheless, the same signs are found in the OLS estimations (Model III & IV).

[30] The coefficients in models I and II (Heckman results) are also negative, though insignificant. The coefficients between firm size (LogEmp and LogTurn) and different types of effects of organisational innovation are also found to be significant and negative in the detailed OLS estimates (results not documented here; available upon request).

accumulated more skills and knowledge by means of organisational learning over time (Amburgey et al., 1990; Nelson and Winter, 1982), on the other.

In addition, the OLS results demonstrate that all of the three types of organisational innovation do have a significant effect on firm performance.[31] The Norwegian firms benefited, to a large extent, from a change in firms' structure (ORGSTR), and to a lesser extent, from a change in knowledge management systems (ORGSYS) and a change in external relationships (ORGREL).[32] Nonetheless, it should be noted that, from all of the estimations made, industry heterogeneity does not seem to play a strong role in explaining the rate and effects of organisational innovation at the firm level. This corresponds in part to recent works, for example, by Leiponen and Drejer (2007) and Srholec and Verspagen (2008), which argue that heterogeneity at the firm level is much greater compared with industrial and national ones when it comes to innovation activities.

6. Concluding Discussion

Using a novel dataset based on the firm-level Norwegian CIS (1999 – 2001 and 2002 – 2004) and financial accounts, this chapter has examined the determinants and performance effects of organisational innovation within firms. In doing so, the study has taken into account the possibility of sample selection bias in the econometric analysis, since only the 'organisational innovators', which account for about one third of the sampled firms from manufacturing, service and other industries in Norway, were included in the analysis of the effects of organisational innovation. Heckman's (1979) two-step estimation was employed, and supported the rejection of significant selection bias.

The chapter provides some important findings which appear to shed light on the influence of several factors in organisational innovation, as well as to offer a few managerial implications. The evidence shows that the probability of attempting organisational change (again) increases with a prior history of the change itself, i.e. repeated/persistent organisational change, which appears to be essential to the improvement of firm performance. This probability may also be

[31] The results (not reported here; available upon request) of a detailed analysis of different effects (six types of effects as dependent variables, one at a time) of these three types of change also go along similar lines as the evidence discussed here using factor score (EFORG) as a dependent variable.

[32] This finding somewhat conflicts with the basic view of organisational ecologists, that change in an organisation's structural core, which naturally impinges on, or even disrupts, some of its existing major routines (i.e. reduces reliability and accountability), hinders its performance.

higher when profitability declines. On the other hand, such attempts are likely to be discouraged by high reported costs of innovation. Moreover, the study finds that firm age, regarded as a very complex determinant in organisational ecology research (see, for example, Carroll and Hannan, 2000), does not significantly influence the effects of organisational innovation, but does exercise some influence over the likelihood of such innovation being undertaken; that is, older firms seem to be more inclined to pursue organisational innovation. In terms of firm size, the results suggest that this may influence the effects of the organisational innovation undertaken; that is, smaller firms seem to receive greater performance benefits from organisational change. Nevertheless, it is unclear from the econometric analysis how firm size influences the decision to pursue organisational innovation, despite the implication of the descriptive statistics that the larger the firm, the more likely it will be to attempt organisational innovation.

The influence of diversity of organisational change on firm performance has also been partially assessed, and the evidence shows that the three types of change considered affect firm performance to different degrees. In addition, the effects appear to be more impressive within firms with the combined presence of technological and organisational innovation. Put differently, firms can better reap the rewards of reorganisation by jointly reorganising with technological innovation.

However, it is important to acknowledge several limitations in this study. Since the Norwegian CIS4 was conducted around the middle of 2005, there was only a short time for the respondent organisational innovators to realise the effects of organisational innovation introduced between 2002 and 2004. Therefore, the analysis could only show how the firms benefited from organisational change in the near term. This limitation relates to the cross-sectional nature of data from the CIS, which may also lead to a simultaneity problem in some cases, because certain variables (which refer to the same, or an overlapping, time period) included in an estimate may be jointly determined. Furthermore, the relationships between some of the variables included in the analysis in the present study may have been influenced by common method bias, because they were extracted from the CIS questions which used similar scale format and/or anchors.[33] This bias may have been the case, since these questions

[33] Strong correlations between such variables may have been, in part, due to this reason. Criscuolo et al. (2007) explain that, in order to attempt to avoid this bias, the CIS questionnaire was designed to incorporate a mixture of Likert scales and questions which required responses in a binary (yes/no) or numerical format (absolute

were answered based, in part, on the (same) respondents' (subjective) evaluation. The reliance on the respondents' subjective knowledge or perception may also have led to subjective indicators in the estimate, such as in the case of the CIS questions about obstacles to innovation (Clausen, 2008).

More importantly, some of the arguments in the present study were made based primarily on prior research, since the analysis could only be done using a reduced form of (representation of) the complex set of relationships, particularly between age and size on the one hand, and structural inertia or rigidity of organisational routines, on the other. The reason these complex relationships could not be empirically tested is simply that there is no information in the CIS which can directly measure complexity, political force, path dependency and other inertia properties (i.e. 'unobserved heterogeneity' in the model). Beck et al. (2008) indicate that many empirical studies of issues related to organisational change neglect unobserved heterogeneity, which potentially causes bias in estimated results. They suggest that, in order to deal with this methodological problem, fixed-effects models may be used when analysing panel data. This is not applicable to the present study, which is based on cross-sectional data. Nonetheless, a residual analysis was conducted for predicted values (regressions with the effects of organisational innovation as dependent variables), as well as the explanatory variables employed, such as age and size, and the results (not reported here) show no sign of endogeneity or the influence of such unobserved heterogeneity (technically, this is consistent with the normal-errors assumption).

Furthermore, it can be argued that the data on organisational innovation made available by the CIS4 is not very detailed. The CIS4 provides only three measures with no scaling of the magnitude of organisational innovation, and, as discussed earlier, these measures are at the firm level (but not plant- or project-level). Therefore, the heterogeneity of organisational innovation within and among firms could not be taken into account in greater detail in this study. However, there may still be other interesting 'organisational' issues to be investigated on the basis of the CIS data (arguably, the most detailed large-scale survey data currently available for innovation research). For example, it is possible to look further into the

numbers, percentages), so that the respondents needed to answer the questions in different parts in different ways. For example, the variables used to measure organisational innovation and its effects in this analysis were extracted from two (consecutive) question sets which were associated with yes/no and Likert-scale items. As described above, the variables for (the three types of) organisational innovation are binary, while the variables for (the six types of) its effects have a scale of 0 – 3.

differential and complementary effects of different types of organisational innovation (such as by means of a multivariate analysis), or of different combinations of technological and organisational innovation. The relationship between knowledge or skilled workers and organisational change also remains to be explored.[34] These are examples of important research topics which, nonetheless, go well beyond the scope of this study.

[34] For instance, Leiponen (2000, 2005) empirically analyses the relationship between firms' innovation and their employees' skills/competencies, and suggests that this relationship is complementary. However, her analyses concern innovation in a rather technological sense, e.g. R&D and product/process innovation.

References

Aldrich, H. (1999), *Organisations Evolving.* SAGE: London.

Aldrich, H. and Auster, E. (1986), 'Even dwarfs started small: liabilities of age and their strategic implications', *Research in Organisational Behavior*, **8**, 165-198.

Amburgey, T. L. and Miner, A. S. (1992), 'Strategic momentum. The effects of repetitive, positional, and contextual momentum on merger activity', *Strategic Management Journal,* **13**, 335-348.

Amburgey, T. L., Kelly, D. and Barnett, W. P. (1993), 'Resetting the Clock: The Dynamics of Organisational Change and Failure', *Administrative Science Quarterly,* **38(1)**, 51-73.

Arrow, K. (1962), 'The Economic Implications of Learning by Doing', *The Review of Economic Studies,* **29(3)**, 155-173.

Arthur, W. B. (1994), *Increasing Returns and Path Dependency in the Economy*. University of Michigan Press: Ann Arbor.

Barnett, W. and Carroll, G. (1995), 'Modeling internal organisational change', *Annual Review of Sociology*, **21**, 217-236.

Beck, N., Bruderl, J. and Woywode, M. (2008), 'Momentum or deceleration? Theoretical and methodological reflections on the analysis of organisational change', *Academy of Management Journal*, **51(3)**, 413-435.

Becker, M., Lazaric, N., Nelson, R. R. and Winter, S. G. (2005), 'Applying organisational routines in understanding organisational change', *Industrial and Corporate Change,* **14(5)**, 775-791.

Beckmann, M. J. (1977), 'Management Production Functions and the Theory of the Firm', *Journal of Economic Theory*, **14**, 1-18.

Bresnahan, T. F., Brynjolfsson, E. and Hitt, L. M. (2002), 'Information Technology, Workplace Organisation, and the Demand for Skilled Labor: Firm–Level Evidence', *Quarterly Journal of Economics*, **117**, 339-376.

Bruland, K. and Mowery, D. (2004), 'Innovation through time', in Fagerberg, J., Mowery, D., Nelson, R. (eds.), *The Oxford Handbook of Innovation*. Oxford University Press: Oxford.

Brynjolfsson, E. and Hitt, L. (2000), 'Beyond Computation: Information Technology, Organisational Transformation and Business Performance', *Journal of Economic Perspectives*, **14(4)**, 23-48.

Brynjolfsson, E. and Hitt, L. (2003), 'Computing Productivity: Firm-Level Evidence', *The Review of Economics and Statistics*, **85(4)**, 793-808.

Brynjolfsson, E. and Mendelson, H. (1993), 'Information Systems and the Organisation of Modern Enterprise', *Journal of Organisational Computing,* **3**, 245-255.

Brynjolfsson, E., Hitt, L. and Yang, S. (2002), 'Intangible Assets: Computers and Organisational Capital', *Brookings Papers on Economic Activity*, **1**, 137-198.

Carroll, G. R. and Hannan, M. T. (2000), *The Demography of Corporations and Industries.* Princeton University Press: New Jersey.

Catozzella, A. and Vivarelli, M. (2007), 'The Catalysing Role of In-House R&D in Fostering the Complementarity of Innovative Inputs', IZA Discussion Paper No. 3126.

Cefis, E. and Orsenigo, L. (2001), 'The Persistence of Innovative Activities: a cross-countries and cross-sectors comparative analysis', *Research Policy*, **30**, 1139-1158.

Chandler, A. (1962), *Strategy and Structure*. MIT Press: Massachusetts.

Clausen, T. (2008), 'Search pathways to innovation', TIK Working Papers on Innovation Studies, Centre for Technology Innovation and Culture, University of Oslo.

Coch, L. and French, J. (1948), 'Overcoming resistance to change', *Human Relations,* **1**, 512-532.

Cohen, W. and Levin, R. (1989), 'Empirical Studies of Innovation and Market Structure', in Schmalensee, R. and Willig, R. (eds.), *Handbook of Industrial Organisation, Vol. 2*. Elsevier: the Netherlands.

Crepon, B. and Duguet, E. (1997), 'Estimating the innovation function from patent numbers: GMM and Count panel data', *Journal of Applied Econometrics*, **12(3)**, 243-263.

Criscuolo, P., Nicolau, N. and Salter, A. (2007) 'The elixir or burden of youth? Exploring differences among start-ups and established firms in innovation behaviour', paper presented at the DRUID summer conference 2007, Copenhagen, 18 -20 June.

Cyert, R. M. and March, J. G. (1963), *A Behavioral Theory of the Firm.* Prentice Hall: New Jersey.

Daft, R. L. (1978), 'A Dual-Core Model of Organisational Innovation', *Academy of Management Journal*, **21(2)**, 193-210.

Damanpour, F. (1987), 'The Adoption of Technological, Administrative and Ancillary Innovations: Impact of Organisational Factors', *Journal of Management*, **13(4)**, 675-688.

Damanpour, F. (1991), 'Organisational innovation: a meta-analysis of effects of determinants and moderators', *Academy of Management Journal*, **34(3)**, 555-590.

David, P. A. (1994), 'Why are Institutions 'the Carriers of History'?: Path Dependence and the Evolution of Conventions, Organisations and Institutions', *Structural Change and Economic Dynamics*, **5(2)**, 205-220.

Dosi, G. (1988), 'Sources, Procedures, and Microeconomic Effects of Innovation', *Journal of Economic Literature*, **26(3)**, 1120-1171.

Dosi, G. and Nelson, R. (1994), ‘An introduction to evolutionary theories in economics’, *Journal of Evolutionary Economics*, **4**, 153-72.

Downs, A. (1967), *Inside Bureaucracy*. Little, Brown: Boston.

Edquist, C., Hommen, L. and McKelvey, M. (2001), *Innovation and Employment: Process versus Product Innovation*. Elgar: Cheltenham.

Evan, W. M. (1966), ‘Organisational Lag’, *Human Organisation,* **25(1)**, 51-53.

Evangelista, R. (2000), ‘Sectoral Patterns of Technological in Services’, *Economics of Innovation and New Technologies,* **9**, 183-221.

Fagerberg, J. (2003), ‘Schumpeter and the Revival of Evolutionary Economics: An appraisal of the Literature’, *Journal of Evolutionary Economics*, **13**, 125-59.

Fagerberg, J. (2004), ‘Innovation: A guide to the literature’, in Fagerberg, J., Mowery, D., Nelson, R. (eds.), *The Oxford Handbook of Innovation*. Oxford University Press: Oxford.

Fagerberg, J. and Verspagen, B. (2009), ‘Innovation studies – The emerging structure of a new scientific field’, *Research Policy,* **38(2)**, 218-233.

Flaig, G. and Stadler, M. (1994), ‘Success breeds success: the dynamics of the innovation process’, *Empirical Economics,* **19**, 55-68.

Freeman, C. (1995), ‘The ‘National System of Innovation’ in Historical Perspective’, *Cambridge Journal of Economics*, **19**, 5-24.

Freeman, C. and Louca, F. (2002), *As Time Goes By: From the Industrial Revolutions to the Information Revolution*. Oxford University Press: Oxford.

Freeman, C. and Perez, C. (1988), ‘Structural Crisis of Adjustment’, in Dosi G., Freeman, C., Nelson, R., Silverberg, G. & Soete, L. (eds.), *Technical change and economic theory*. Pinter Publishers: London.

Galia, F. and Legros, D. (2004), ‘Complementarities between obstacles to innovation: evidence from France’, *Research Policy*, **33**, 1185-1199.

Geroski, P. A., van Reenen, J. and Walters, C. F. (1997), ‘How Persistently do Firms Innovate?’, *Research Policy*, **26(1)**, 33-48.

Greve, H. R. (1998), ‘Performance, Aspirations, and Risky Organisational Change’, *Administrative Science Quarterly*, **44**, 58-86.

Greve, H. R. (1999), ‘The effect of core change on performance: inertia and regression toward the mean’, *Administrative Science Quarterly,* **37**, 48-75.

Greve, H. R. (2003), *Organisational Learning From Performance Feedback: A Behavioral Perspective on Innovation and Change.* Cambridge University Press: Cambridge.

Hall, B. H. (2002a), ‘The financing of research and development’, *Oxford review of economic policy,* **18**, 35-51.

Hall, B.H. (2002b), ‘Notes on Sample Selection Models’, Mimeo, available online at http://emlab.berkeley.edu/users/bhhall/sampsel.pdf, Accessed on 29 June 2007.

Hannan, M. T. and Freeman, J. H. (1977), ‘The Population Ecology of Organisations’, *American Journal of Sociology*, **82**, 929-964.

Hannan, M. T. and Freeman, J. H. (1984), ‘Structural Inertia and Organisational Change’, *American Sociological Review*, **49(2)**, 149-64.

Heckman, J. (1976), ‘The common structure of statistical models of truncation, sample selection, and limited dependent variables and a simple estimator for such models’, *Annals of Economic and Social Measurement,* **5**, 475-492.

Heckman, J. (1979), ‘Sample selection bias as a specification error’, *Econometrica*, **47(1)**, 153-161.

Kamien, M. I. and Schwartz, N. L. (1975), 'Market Structure and innovation: A survey', *Journal of Economic Literature,* **13(1)**, 1-37.

Kamien, M. I. and Schwartz, N. L. (1982), *Market Structure and innovation.* Cambridge University Press: Cambridge.

Kelly, D. and Amburgey, T. L. (1991), 'Organisational Inertia and Momentum: A Dynamic Model of Strategic Change', *Academy of Management Journal*, **34(3)**, 591-612.

Kimberly, J. R. (1976), 'Organisational size and the structuralist perspective: a review, critique and proposal', *Administrative Science Quarterly,* **21**, 571-597.

Kimberly, J. R. and Evanisko, M. J. (1981), 'Organisational Innovation: The influence of individual, Organisational, and Contextual Factors on Hospital Adoption of Technological and Administrative Innovation', *Academy of Management Journal*, **24(4)**, 689-713.

Kline, S. J. and Rosenberg, N. (1986), 'An overview of innovation', in Landau, R. and Rosenberg, N. (eds.), *The positive sum strategy: harnessing technology for economic growth*. National Academy Press: Washington DC.

Knott, A. M. (2001), 'The dynamic value of hierarchy', *Management Science,* **47**, 430-448.

Lam, A. (2004), 'Organisational Innovation', in Fagerberg, J., Mowery, D., Nelson, R. (eds.), *The Oxford Handbook of Innovation*. Oxford University Press: Oxford.

Lazonick, W. (2004), 'The Innovation Firm', in Fagerberg, J., Mowery, D., Nelson, R. (eds.), *The Oxford Handbook of Innovation*. Oxford University Press: Oxford.

Leibenstein, H. (1987), *Inside the Firm: The Inefficiencies of Hierarchy.* Harvard University Press: Massachusetts

Leiponen, A. (2000), 'Competencies, innovation and profitability of firms', *Economics of Innovation and New Technologies*, **9**, 1-24.

Leiponen, A. (2005), ‘Skills and innovation’, *International Journal of Industrial Organization,* **23**, 303-323.

Leiponen, A. and Drejer, I. (2007), ‘What exactly are technological regimes? Intra-industry heterogeneity in the organisation of innovation activities’, *Research Policy*, **36**, 1221-1238.

Levinthal, D. A. (1991), ‘Organisational adaptation and environmental selection – interrelated processes of change’, *Organisation Science,* **2(1)**, 140-145.

Levinthal, D. A. and March, J. G. (1981), ‘A model of adaptive organisational search’, *Journal of Economic Behavior and Organisation,* **2**, 307-333.

Malerba, F. and Orsenigo, L. (1999), ‘Technological entry, exit and survival: an empirical analysis of patent data’, *Research Policy,* **28(6)**, 643-660.

March, J. G. and Shapira, Z. (1992), ‘Variable risk preferences and the focus of attention’, *Psychological Review,* **99**, 172-183.

March, J. G. and Simon, H. A. (1958), *Organisations.* Wiley: New York.

Martin, B. R. (2008), ‘The Evolution of Science Policy and Innovation Studies’, TIK Working Papers on Innovation Studies, Centre for Technology Innovation and Culture, University of Oslo.

Miles, I. (2004), ‘Innovation in Services’, in Fagerberg, J., Mowery, D., Nelson, R. (eds.), *The Oxford Handbook of Innovation*. Oxford University Press: Oxford.

Mohr, L. B. (1969), ‘Determinants of Innovation in Organisations’, *The American Political Science Review*, **63(1)**, 111-126.

Nelson, R. R. (1991), ‘Why do firms differ, and how does it matter?’, *Strategic Management Journal*, **12**, 61-74.

Nelson, R. R. and Winter, S. G. (1982), *An Evolutionary Theory of Economic Change*. Harvard University Press: Massachusetts.

Peters, B. (2009), ‘Persistence of Innovation: stylized facts and panel data evidence’, *Journal of Technology Transfer,* **34(2)**, 226-243.

Pettigrew, A. M. and Fenton, E. M. (2000), *The Innovating Organisation*. SAGE: London.

Penrose, E. T. (1959), *The theory of the growth of the firm.* Wiley: New York.

Pfeffer, J. (1992), *Managing with Power: Politics and Influence in Organisations*. Harvard Business School Press: Massachusetts.

Porter, M. (1980), *Competitive Strategy.* Free Press: New York.

Porter, M. (1985), *Competitive Advantage.* Free Press: New York.

Raymond, W., Mohnen, P., Palm, F. and van der Loeff, S. S. (2006), ‘Persistence of innovation in Dutch manufacturing: is it spurious?’, CESifo Working Paper No. 1681.

Romanelli, E. and Tushman, M. L. (1994), ‘Organisational Transformation as Punctuated Equilibrium: An Empirical Test’, *Academy of Management Journal*, **37(5)**, 1141-1166.

Rosenberg, N. (1976), *Perspectives on Technology*. Cambridge University Press: Cambridge.

Sapprasert, K. (2009), ‘Acknowledging Organisational Innovation’, in Ostreng, W. (ed.), *Confluence: Interdisciplinary Communications 2007/2008*. Centre for Advanced Study at the Norwegian Academy of Science and Letters: Norway.

Scherer, F. M. (1980), *Industrial market structure and economic performance.* Rand McNally: Chicago.

Schumpeter, J. (1911), *The Theory of Economic Development*. Harvard University Press: Massachusetts.

Schumpeter, J. (1939), *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process*. 2 volumes, McGraw-Hill: New York.

Schumpeter, J. (1942), *Capitalism, Socialism and Democracy*. Routledge: London.

Simon, H. A. (1962), 'The Architecture of Complexity', *Proceedings of the American Philosophical Society*, **106**, 67-82.

Sirilli, G. and Evangelista, R. (1998), 'Technological innovation in services and manufacturing: results from Italian surveys', *Research Policy*, **27(9)**, 881-899.

Sorensen, J. B. and Stuart, T. E. (2000), 'Age, Obsolescence, and Organisational Innovation', *Administrative Science Quarterly*, **45(1)**, 81-112.

Srholec, M. and Verspagen, B. (2008), 'The Voyage of the Beagle in Innovation Systems Land: Exploration on Sectors, Innovation, Heterogeneity and Selection', TIK Working Papers on Innovation Studies, Centre for Technology Innovation and Culture, University of Oslo.

Stinchcombe, A. (1965), 'Social Structure and Organisations', in March, J. (ed.), *Handbook of Organisations*. Rand McNally: Chicago.

Sutton, J. (1991), *Sunk costs and market structure*. MIT Press: Massachusetts.

Teece, D. J. (1980), 'The Diffusion of an Administrative Innovation', *Management Science*, **26(5)**, 464-470.

Teece, D. and Pisano, G. (1998), 'The dynamic capabilities of firms: an introduction', in Dosi, G., Teece, D., Chytry, J. (eds.), *Technology, Organisation and Competitiveness: Perspectives on Industrial and Corporate Change*, Oxford University Press: Oxford.

Tushman, M. L. and Romanelli, E. (1985), 'Organisational evolution: a metamorphosis model of convergence and reorientation', in Cummings L. L. and Staw B. M. (eds.), *Research in Organisational Behavior,* 171-222.

Veugelers and Cassiman (1999), 'Make and buy in innovation strategies: evidence from Belgian manufacturing firms', *Research Policy*, **28(1)**, pp.63-80.

Witt, U. (1998), 'Imagination and leadership: the neglected dimensions of the evolutionary theory of the firm', *Journal of Economic Behavior and Organisation,* **35**, 161-177.

Zucker, L. G., Darby, M. R. and Armstrong, J. (1998), 'Geographically Localized Knowledge: Spillovers or markets?', *Economic Inquiry*, **36**, 65-86.

APPENDIX

Table A.1: Principal components analysis for the effects of organisational innovation

Effects of Organisational Innovation	Factor Loadings
	EFORG
Reduced response time to customer needs	0.639
Improved quality of goods or services	0.699
Reduced costs per unit output	0.639
Improved employee satisfaction and/or reduced employee turnover	0.600
Increased enterprise's capacity	0.772
Higher enterprise's profitability	0.734

Note: One factor with eigenvalue greater than 1 detected, which explains 47 % of total variance.

Table A.2: Correlation matrix for the explanatory variables employed in the model

	Age	Emp	Turn	PASTORG	PASTPERF	HCOST	HFUND	HPER	INCOMP	ORGSYS	ORGSTR
Age	1.000										
Emp	0.118	1.000									
Turn	0.050	0.595	1.000								
PASTORG	0.006	0.115	0.051	1.000							
PASTPERF	-0.102	-0.008	-0.050	0.004	1.000						
HCOST	-0.086	0.001	-0.011	0.149	0.016	1.000					
HFUND	-0.096	0.022	-0.006	0.135	0.034	0.762	1.000				
HPER	-0.052	0.054	0.036	0.122	-0.002	0.556	0.555	1.000			
INCOMP	-0.030	0.084	0.039	0.230	-0.002	0.387	0.355	0.330	1.000		
ORGSYS	0.001	0.132	0.080	0.129	-0.024	0.126	0.142	0.138	0.250	1.000	
ORGSTR	-0.009	0.160	0.063	0.181	0.014	0.186	0.200	0.181	0.228	0.434	1.000
ORGREL	-0.013	0.144	0.020	0.123	0.043	0.177	0.163	0.125	0.142	0.257	0.400

Note: Age, Emp (Number of employees), Turn (Total Turnover) and PASTORG (Past/Persistent Organisational Change) are included in Heckman-Stage 1 & 2 and OLS estimation. INCOMP (Complementarity) is included in Heckman-Stage 2 and OLS estimation. PASTPERF (Productivity Growth), HCOST (High Innovation Costs), HFUND (Lack of Funds) and HPER (Lack of Qualified Personnel) are included in Heckman-Stage 1. ORGSYS, ORGSTR and ORGREL are included in OLS estimation.